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# Undesirable Insect Aliens

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An alien, under the immigration laws of this country, is any person not native born or a naturalized citizen of the United States. While our forefathers early appreciated the need for controlling the entry of individuals who desired to establish residence in this country, there appears to be no evidence to indicate that they entertained any fears with respect to the insect pests of other countries. On the contrary, they and their descendants unwittingly aided and abetted the introduction and subsequent dissemination of these champion "hitchhikers" of all time. This condition is not surprising when we take into account the fact that most of our agricultural products, such as vegetables, fruits, cereals, and field crops, represent importations which, until 1912, were made without any plant-quarantine restrictions whatsoever. One of the earliest attempts to introduce plants into this country which has come to the attention of the speaker is that referred to by a Puerto Rican historian, who relates that the real reason which led Columbus to land in Puerto Rico on his second voyage in 1493 was the need for water, the scanty supply in his little fleet having been exhausted in keeping alive the stock of living plants which were being carefully carried to the new continent.

Infrequent sailings, slow transportation, and the normal life cycle of foreign insects retarded the ingress of many species in the early days of the Republic, but even under those adverse conditions some did enter and become established. While it is a matter of conjecture, it would seem reasonable to presume that the bedbug, roaches and the housefly were among the first to be introduced, although there seems to be no published record to that effect. Search of the literature seems to indicate that the Angoumois grain moth, early referred to as the "fly weevil," was first recognized as a pest in America in 1728. Twenty years later Peter Kalm, a pupil of Linné, visited the American Colonies and reported that the pea weevil was destroying whole fields of peas, being established in Pennsylvania, New Jersey, and southern New York. The injury occasioned by this insect was a matter of concern to Kalm, who was of the opinion that it represented a native species and one which should be kept out of Sweden. He states:

> "It is clearly to be wished that none of the ships which annually depart from New York or Pennsylvania will bring them into the European countries. From the above the powers of a single despicable insect will plainly appear; and also that the study of entomology is not to be looked upon as a mere pastime and useless employment."

On his return to Stockholm in 1751 he discovered that some of the peas that he took with him were hollow and the heads of the insects were protruding from the cavities. This caused him to close the package quickly for fear that the adults would emerge, escape, and become established in Sweden. Despite this belief that the pea weevil was a native of the United States, Linné states that the pea weevil was at that time established in the countries of southern Europe. Even so, it would appear that Kalm was one of the first to recognize the pest risk which accompanies the importation of plant products and the part that vessels may play in introducing insect pests as stowaways or otherwise.

Other injurious insects which were of record as being established in the United States in the 18th century include, in part, the clothes moth, the codling moth, the hessian fly, the pear slug, and the oyster-shell scale. These records appeared

in literature during the period when there were no professional entomologists in America, and our knowledge of insects occasioning injury at that time is based largely on observations recorded by amateur collectors. It is quite possible, therefore, that some of the introduced insects which came into prominence during the succeeding century were actually established in this country in the 18th century but had not been observed. Then too, there is the possibility that some insects introduced prior to or during the early part of the 18th century became established but actually, for some reason, failed to survive. For example, we are told that the asparagus beetle was observed as early as 1801, later disappeared, and did not become permanently established until about 1856.

Increased transportation facilities involving speedier, larger, and refrigerated ships, with the corresponding increase in commerce during the 19th century, resulted in the appearance of such insect pests as the clover root borer, clover leaf midge, clover leaf weevil, green bug, Italian pear scale, European fruit lecanium, apple aphid, white peach scale, hemispherical scale, green shield scale, citrus mealybug, soft scale, Florida red scale, citrus whitefly, Parlatoria date scale, tobacco moth, Argentine ant, black scale, leopard moth, brown-tail moth, gypsy moth, European elm scale, Mediterranean flour moth, sweetpotato weevil, confused flour beetle, rice weevil, horn fly, asparagus beetle, imported cabbage worm, and potato tuber worm. The 20th century witnessed the appearance of such insect pests as the alfalfa weevil, European corn borer, pink bollworm, oriental fruit moth, Japanese beetle, ermine moth, satin moth, European pine shoot moth, European earwig, woolly whitefly, vegetable weevil, white-fringed beetle, Egyptian alfalfa or Berseem weevil, and numerous others.

To enumerate all the foreign insects which have gained lodgment in the United States would require much more time than could be devoted to them here. Despite the rapid advent of insect pests which were becoming established in this country, and exacting a heavy toll on our principal crops,—Walsh, in 1868, estimated that the depredations by insects amounted to $300,000,000 annually —no real attempt to secure appropriate legislation designed to curb their entry was made until 1892 when Representative Caminetti of California introduced a bill in the Congress which was referred to the Committee on Agriculture of the House of Representatives. The earliest concerted effort to obtain Federal legislation designed to prevent the entry of insect pests with imported plants and plant products resulted from a resolution passed by the Ohio State Horticultural Society in 1896. The following year a convention was called in Washington and the first bill to be introduced in Congress, based on the recommendations of this convention, was introduced by Representative Barlow on January 18, 1898. Subsequently other bills were introduced, none of which were enacted. Largely through the persistent efforts of C. L. Marlatt the Plant Quarantine Act of 1912 was finally passed. In the meantime, the wholly inadequate Insect Pest Act of 1905, which applies to the importation or interstate transportation of living insects as such and the use of the United States mails for that purpose, was passed. Considering that over such a long period there was such apparent indifference to, or such a lack of appreciation of, the need for providing means to exclude insect pests, one wonders if the following lines from Whittier's "Corn Song" represented the state of mind which prevailed:

> "Let earth withhold her goodly root,
> Let mildew blight the rye,
> Give the worm the orchard fruit,
> The wheat field to the fly."

What were other nations doing to stem the tide of foreign insects during the period under review? To the best of our knowledge the first regulation or decree directed against a foreign insect was that of Germany, in 1873, which, curiously enough, had reference to an American insect, the grape phylloxera. Other nations rapidly followed suit, and it is a sad commentary on our country's leadership that the United States was practically the last of the great nations to adopt measures designed to prevent the entry of injurious insects on or in plants and plant products. In the first annual report on the injurious and other insects of the State of New York, issued in 1883, Lintner states that "America is the home of insects." The long list of introduced

insects which cause enormous losses to our agricultural crops is abundant proof of his assertion. When we take into account the diversified crops grown in this country and the life zones involved in their production, there are few insects of foreign countries which could not thrive in some portion of the United States. Up to the early part of the 20th century man did everything possible to make their entry easy, for he brought them with their hosts, and, furthermore, he speeded up the crossing, even providing refrigeration facilities to prevent deterioration of the host during transit. These introduced insect aliens, for the most part, will remain with us permanently as unwelcome guests, constantly feeding on our crops and forcing us to continue expenditures for their control.

Just what are these insect aliens costing this country? We are informed that the estimated damage occasioned by insects in the United States approximates $1,601,527,000 annually. This figure does not include the cost of maintaining Federal and State research bureaus and experiment stations, of maintaining Federal and State plant quarantine regulatory organizations, the losses sustained in quarantined States due to limitation of markets of the quarantined crops, the various processing costs made necessary by insect depredations, such as screening of grains, washing of fruits to remove excessive poison, and grading of fruits and vegetables to make due allowance for insect damage. It would seem safe to assume that, under present-day conditions, if these items were included, the annual losses occasioned by introduced and native insects in this country would approximate $3,000,000,000. Further, it is believed that at least half of this loss may be charged to imported insects, many of which might have been kept out in early days had there been popular understanding and support for adequate legislation, funds and organizations to enforce such legislation. At the present time there are 127 State and 13 Federal quarantines which apply to introduced insects, as compared to 24, all State quarantines, which pertain to native insects.

It is admitted that the facts cited present a gloomy picture, and with that outlook alone one might, in a moment of depression, be disposed to subscribe to the *laissez-faire* philosophy which was discussed in an annual address before this Association forty years ago. There is no denying that much lasting damage has been done by alien insects, of which we have a goodly share, but this is not the time for us to deplore what has occurred in the past. On the contrary, we have a job in applied entomology which challenges our ingenuity and ability. Listen! There are some 20,000 insects, many with harmful capacities, which have not yet become established in the United States. Many of these insects are knocking daily at our doors, eager to gain entrance. During the fiscal years 1935–1939, inclusive, 234,858 interceptions of insects were made at American ports of entry. It is true that certain species were intercepted on many occasions and in some instances insects already well established in the United States were taken. Interceptions of this type illustrate the constant flow of insects to our ports. But this is not all the picture, for the number indicated includes literally hundreds of species not at present in the United States which, if we may judge by the destructive habits demonstrated by them in the countries of origin, could cause incalculable losses if allowed to become established here. As often expressed in political circles and by way of illustration, "Lets look at the records" as applied to truck-crop insects.

No less than five species of potato weevils, all of which live in and riddle potato tubers, have been intercepted—*Epicaerus cognatus* Sharp from Mexico and *Rhigopsidius tucumanus* Heller, *Premnotrypes solani* Pierce, *Trypopremnon latithorax* Pierce, and *T. sanfordi* Pierce from South America. The potatoes from South America which were infested with the four species just listed are referred to in that engaging book by David Fairchild entitled, "The World Was My Garden," on page 404 of which he states: "The American potato growers were, of course, delighted to have this new material to use in breeding for high yielding, disease resistant varieties." Now the American potato growers may have welcomed these new horticultural acquisitions with great joy, but it is certainly fortunate for them that applied entomology was on the job to prevent the introduction of the weevils.

Particularly is this true owing to the fact that the potatoes in question originated for the most part in the Andean region of South America, under climatic conditions comparable to those which prevail in potato-producing areas in the United States.

Other truck-crop pests intercepted include *Palaeopus costicollis* Marsh., in yams from Germany; *Euscepes postfasciatus* (Fairm.) from the West Indies, Brazil, and New Zealand; *Cylas femoralis* Faust. from Liberia; *Omphisa anastomosalis* (Guen.) from China, India, Ceylon, New Guinea, Siam, the Philippine Islands, and Java in sweetpotatoes; *Baris laticollis* (Marsh.) from France, Portugal, and England; *Ceutorhynchus pleurostigma* (Marsh.) from England, Denmark, Scotland, Holland, Poland, Germany, and France; and *Psylliodes chrysocephala* (L.), from England, Spain, Italy, Norway, the Canal Zone, France, Argentina, Scotland, India, and Holland, all three species in turnips. Horseradish from Czechoslovakia and Poland has on several occasions arrived infested with *Baris lepidii* Germar., and cipollini from Morocco, Italy, and France infested with *Exosoma lusitanica* (L.), a chrysomelid beetle, reported to attack, in the immature stage, certain bulbous plants, and in the adult stage the buds of grape. Two insects capable of doing considerable injury to green beans have been taken on numerous occasions, namely, *Maruca testulalis* (Geyer) from Cuba, Mexico, and the East Indies, and *Epinota opposita* Heinrich, in beans and peppers from Mexico. The last-named insect was described from moths reared from alfalfa and cowpeas in Peru, and therefore does not confine its attacks to truck crops.

The insects mentioned represent just a few of the dangerous foreign pests of truck crops which have been knocking at our doors. A similar hasty glance over the records of foreign insects of other crops which have attempted to gain entry is equally illuminating. To summarize, the Asiatic rice borer, *Chilo simplex* (Butler), a destructive rice pest in the Far East, has been taken many times in rice straw used as packing and covers for bottles. In one instance it arrived at New Orleans in hog feed, composed of rough rice with stems attached, which exhibited a 90 per cent infestation of living larvae. *Agriotes lineatus* (L.), a wireworm which attacks tobacco, clover, hops, and corn in Europe, has been taken in potatoes and rutabagas from England, Italy, Denmark, Germany, Spain, and Sweden. A sugarcane borer, *Metamasius sericeus* (Oliv.) has arrived on numerous occasions from Cuba, Costa Rica, Barbados, the Canal Zone, and Peru. Citrus plants from the Philippine Islands and Japan have arrived infested with *Phyllocnistis citrella* Stainton. This leaf miner, which is of general distribution throughout the Far East, is especially injurious to trees in the nursery. Three seed-infesting insects, *Heilipus lauri* Boheman, *Conotrachelus aguacatae* Barber, and *Stenoma catenifer* Wlsm., have been taken many times in avocado seed from Mexico, Honduras, Guatemala, Costa Rica, Ecuador, and British Honduras. Grapes from Hungary and Italy have been found to be infested with the larvae of *Polychrosis botrana* (Schiffermüller), an injurious tortricid which attacks the blossoms and fruit; and persimmon fruit arriving in baggage from Italy was found to be infested with *Stephanitis pyri* (F.), a serious pest of pear and apple in Europe. *Earias insulana* (Bdv.), a noxious cotton pest, the larvae of which feed in the bolls and squares, has been intercepted in cotton from Ceylon and the island of Cypress. Various varieties of cherry seed from France, Denmark, Austria, Bulgaria, and Czechoslovakia have been infested with *Anthonomus rectirostris* (L.). The immature stage of this insect feeds on the seed, frequently preventing ripening of the fruit.

Some of the fruitflies which have been taken include *Dacus oleae* Gmel. in olives from France, Greece, Italy, Portugal, South Africa, and Spain; *Ceratitis capitata* (Wied.) in a variety of fruits from various countries; and *Anastrepha grandis* (Macq.) in pumpkins from Brazil and Argentina.

Thus far we have referred to only a few of the numerous species of insects which have actually been intercepted at our ports of entry. No mention has been made of forms which have been taken and which have a limited distribution in this country, such as the pink bollworm, Mexican fruitfly, and European corn borer. Those who have had occasion to refer to the literature of foreign insects are

familiar with the countless species which should be guarded against. By way of illustration, Clausen lists 170 species of insects which attack field crops and 176 which attack forest trees in Japan, many of which do not occur in the United States. It is no longer necessary, however, to theorize as to the risk which accompanies the importation of plants and plant products, as was the case prior to the passage of the Plant Quarantine Act of 1912, for the annual lists of intercepted plant pests published by the Bureau of Entomology and Plant Quarantine furnish abundant evidence in this respect.

In directing our efforts to prevent the introduction of insects of other countries, we are confronted with the difficulty of singling out the species which would become troublesome if they should enter. It does not follow that an insect which occasions little injury in the country of origin would be of no significance in the United States. Indeed, if we may judge from past experience, the contrary is the case; for many of our most injurious insect aliens—for example, the San Jose scale, Japanese beetle, white-fringed beetle, alfalfa weevil, and oriental fruit moth—were not regarded as serious pests in their native home. While we should take cognizance of the known injurious insects of other countries, we should not concentrate all our efforts in that direction, but should be mindful of the possibilities which attend the introduction of species which have not demonstrated such destructive capacities in their native habitat.

Fernald, in his address before this Association in 1914, stated: "Another present need of economic entomologists is a better knowledge of foreign insects." During the past 27 years, as the result of inspections at the ports of entry, much valuable information has been assembled regarding the pests of crops of other countries. In some cases these interceptions represented the first records of the occurrence of the insects in question in the countries concerned, whereas in other instances new hosts for the species involved were established. As this work has progressed, new techniques have been developed, with the result that pests which would have escaped attention in the past are now more readily detected. Despite these advancements, however, the plant-quarantine aspect of applied entomology still needs improvement, and many problems are yet to be solved which will test the ingenuity and resourcefulness of those engaged in this work. The information acquired by inspection at the ports of entry and in the literature should be supplemented by evidence secured by field studies in countries exporting plants and plant products to the United States. Such studies should be made by well-trained entomologists possessing a plant-quarantine perspective. If the evidence acquired indicates that eminent risk attends the introduction of the product concerned, appropriate action should be taken. On the other hand, if such risk is not apparent, unnecessary restrictions should not be imposed.

The discovery of alien insects in or on imported products represents but one phase of the problem. To make an intelligent decision as to the proper disposition of such an infested shipment, we must know the identity of the insect concerned. Numerous shipments arrive infested with immature stages only, and material of this nature frequently frustrates the taxonomists owing to the fact that the original, and subsequent, descriptions of many insects are based on characters to be found in the adults alone. Gibson, in his Presidential Address before this Association in 1926, stated, "One of the important needs in applied entomology today is accurate knowledge regarding larval forms of insects." While some progress in this direction has been made in recent years, much yet remains to be done, particularly as applied to foreign insects.

Another problem which has perplexed those engaged in applied entomology is the development of methods of treatment calculated to eliminate pest risk and at the same time not injure the product so treated. Experimental work during the past two decades has resulted in the adoption of such treatments as hot water, hot moist air, low temperatures, use of rollers in crushing cotton seed which may be infested with the pink bollworm, and, more recently, methyl bromide fumigation. While all these have their limitations, they represent progress and permit the enlargement of importations or interstate movement with minimum risk to the country. Even so, there is still urgent

need for further exploration in this field.

The rapid development of aircraft transportation has brought us much closer to the insect pests of foreign countries. This method of transportation has passed the experimental stage and today there are 59 ports which have been designated as air ports of entry for planes arriving from foreign countries. Established lines now have regular service between the United States and countries of Europe, South and Central America, the West Indies, Mexico, Canada, and the Orient. During the fiscal year 1939 prohibited plant material arrived on 779 planes, and during that period 2,445 interceptions of insects were made in cargo shipments, passengers' baggage, and parcel post and as stowaways. One of the cargo problems connected with airplanes from the republics to the south of us is the constant arrival in season of cut flowers for distribution to various points in the United States. Examination of these flowers has resulted in the finding of numerous injurious insects, many of which could readily leave the flowers at destination and perhaps become established. As indicated by Glick and Welch, the insect-stowaway risk which attends the entry of airplanes is also one which presents possibilities. Not only are we concerned with the injury these stowaway insect aliens may occasion to our crops, but as possible vectors of plant or human diseases they present a serious problem. It is conceivable that certain injurious sugarcane diseases, for example, might be introduced with insect vectors despite the fact that sugarcane cuttings or plants are prohibited from all foreign countries. The part that mosquito stowaways may play with respect to introducing human diseases is an established fact. To illustrate, a West African mosquito, *Anopheles gambiae* Giles, dangerous because it carries malaria of a serious and often fatal type, made its appearance on the East Coast of Brazil a few years ago. It is believed that this malaria carrier was brought to Brazil from West Africa as a stowaway on airplanes. Shortly thereafter outbreaks of malaria of unprecedented severity followed the spread of the invading mosquitoes. The insect problem as applied to airplanes is therefore one which also concerns the health of man, and due recognition of this situation has been taken into account by the United States Public Health Service of the Treasury Department. On the subject of insect travel by means of airplanes, Ball, in his Presidential Address before this Association in 1918, stated, "The spirit of conquest is in the air, and if the entomologists are to carry their standard in the forefront of this modern warfare against the enemies of old they must search the rushes for a Moses."

Today we are faced with a condition which should not be minimized, namely, the effect that the deplorable war in Europe may have on the sanitary condition of plants and plant products shipped to this country. There are some who are prone to conclude that the disturbed shipping facilities, which result when wars are in progress, curtail the volume of imports and when such conditions obtain, the risk of importing injurious insects is insignificant. Our experience in the last World War does not support this theory, for during those turbulent days many of the experienced plant quarantine officials, in the countries involved, were called to the colors and their work turned over to less experienced inspectors, resulting in decreased efficiency. Furthermore there is no assurance that a product normally imported from a certain European country will not be imported from another country when wars intervene to disrupt commercial relations. Indeed it may be noted that the effects of the present war on the sanitary condition of certain types of plant material has already been evident, due perhaps to an effort to dispose of as many plants as possible while shipping conditions permitted.

There are at least two outstanding examples of injurious insects which were introduced into a country with materials needed in connection with the prosecution of a war. The Hessian fly is presumed to have arrived in this country in straw used as bedding during the Revolutionary War, and the Colorado potato beetle accompanied potatoes shipped to the American Expeditionary Forces during the last World War. The Colorado potato beetle not only became established in France but has spread to other European countries. A press release from Germany just prior to the present war indicated that the Colorado potato beetle was regarded as the nation's greatest enemy and that

drastic measures were being adopted to combat this pest which threatens a food crop so essential to their daily life.

Wars are expensive and devastating but fortunately they are of relatively short duration. An introduced insect which may have gained lodgment during the period of a war usually remains as a permanent alien and its board bill frequently reaches prodigious figures. By way of illustration, Walton and Packard state that the damage occasioned by the Hessian fly in the United States has amounted to at least $100,000,000 in a single year. Imagine what this insect alone has cost this country during the past one hundred and sixty years! When we take into account the facts cited, it is clearly evident that there should be no relaxation in our plant quarantine efforts because of the present disturbed conditions in Europe but rather we should strengthen our front and be constantly on guard to prevent the entry of insect aliens.

Howard, in an address before the Peninsula Horticultural Society forty-five years ago, commented, "That 'in commerce is the wealth of nations' is a very old and well known truth; but that in commerce is also the means of destroying the wealth of nations is an equal truth which has only become apparent in comparatively late years. It is by commerce that injurious insects, noxious weeds and fungous and bacterial diseases of cultivated plants have become and are becoming distributed over the face of the globe." The situation today is even more acute than was the case when the words just quoted were uttered, for modern transportation now affords insect pests optimum traveling facilities, and it is apparent from the records that they have taken, and are taking, advantage of these facilities made by man.

Since man is responsible for the presence of many costly pests which have come to us, self-preservation requires that he devise effective means to prevent the arrival and establishment of additional insect pests. This cannot be accomplished by paper quarantines alone. In considering the protection of this country against foreign insect pests, we might liken it to a military problem. Though the details of the problem at hand may differ widely from that of true military operations, yet there is sufficiently close analogy to justify consideration of army methods. Our tactics may be different but our strategy will somewhat resemble theirs.

Should we not have more than a single line of defense against the insects which persistently keep knocking at our doors? The "thin red line" of history fires the imagination with its dramatic appeal but every general staff sleeps sounder if it can interpose a series of bulwarks between the enemy and the country to be attacked. War has taught every army the advantage of multiple defense. Applying this strategy to insect pest protection, it is evident that we would be much more secure if, instead of one line of defense at the ports of entry, we could establish other barriers with organized lines of communication. One might suggest that we should have three lines of defense. The first should be in the terrain of the pests to be kept out, the second at the ports of entry, and the third might be regarded as a home defense organized to take care of any insects which might escape the other two.

The first line of defense would comprise a group of scout entomologists, a fact-finding body of men. The facts, investigations, reports, data, and advice which they could provide would be valuable to the administrative officers and to those located at the ports of entry. These scout entomologists could not only give warning of what was dangerous to import from an insect standpoint but could give assurance in many instances as to the safety of certain commodities and thus make possible the movement of the maximum of commerce with the minimum of risk.

The second line of defense would be at the ports of entry where those so engaged have been battling against great odds. Some of the accomplishments of this little group of plant-quarantine men have already been referred to briefly.

The third element might be likened to our National Guard and is more of a system than a line. It need not comprise a specific body of men but should be a prearranged plan of action. It is the reserve to be used in cases of emergency. It is the provision for dealing with the unexpected, the sudden, the accidental introduction of an insect, and when such a pest is discovered this reserve should be

prepared to meet the intruder immediately and in full force. To be effective this three-fold defense should have behind it the full power and purpose of the people. With a line of scouts in the home of the would-be invader, a frontier defense in the form of an effective port inspection service, and a third line of defense prepared to eradicate an infestation quickly in its incipiency, we could be more hopeful of remaining free from these costly and disturbing foreign insect aliens.

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# Fifty Years of Entomological Progress, Part I, 1889 to 1899

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INTRODUCTION.—The story of the first decade of this Association would seem to call for at least a brief reference to its founding meeting. This meeting was held near Toronto, Canada, on a bluff overlooking Lake Erie, August 30, 1889, in response to a call issued by Mr. James Fletcher, President of the Entomological Club of the American Association for the Advancement of Science.

A small group of some nine persons founded this new Association—those listed in Dr. Howard's account (Insect Life, Vol. VII, page 56) being: A. J. Cook, presiding; J. B. Smith, acting as secretary; and Dr. C. J. S. Bethune, Mr. Fletcher, Mr. E. Baines Reed, Mr. H. H. Lyman, Prof. C. W. Hargitt, Mr. E. P. Thompson and Dr. L. O. Howard. This group adopted the name "Association of Official Economic Entomologists," the word "Official" being later dropped. It also adopted a constitution, provided for an adjourned meeting in Washington in November of the same year, and elected the following officers for that meeting: C. V. Riley, president; S. A. Forbes and A. J. Cook, vice presidents; and J. B. Smith, secretary.

My time will not permit a discussion of the meetings of this decade, but merely to indicate growth—the attendance at the First Annual Meeting (November, 1889) was 20, and at the Tenth (1898) 26 members were recorded as present, and a total of 99 active and 32 foreign members were listed. Contrasting this total of 99 active members listed in the report of the last Annual Meeting of this first decade with the active membership of some 1,500 at this, our golden anniversary meeting, and also the meager funds available fifty

and forty years ago (Division of Entomology $20,000 annually) with the many millions annually in our last decades—are we to infer that the accomplishments and output of these subsequent periods of our half-century of existence will have increased in like proportion? The chroniclers of the next four decades have the answer.

THE RECORD OF THE FIRST DECADE.—Turning now to the record of the first decade of this Association, you will appreciate that it will not be possible in the time at my disposal to note the important studies which were made in this period by some 100 different agencies in the United States and in Canada, in relation both to our many native and to our long-established insect pests. A mere list of such studies would take more time than has been assigned to me. I have therefore decided to cover, and that very briefly, the important new subjects that arose in the decade, most of which have continued through our fifty-year period. Carrying out this plan, I shall give (1) a brief chronological statement of the important new insects, useful and harmful; (2) a discussion of biological control as having had its first great demonstration in this period; (3) a statement of the advances in insecticides; and (4) certain epoch-making discoveries in medical entomology. This will be followed by brief accounts of the three outstanding new insect pests of the period—viz., the gipsy moth, the Mexican cotton boll weevil, and the San Jose scale. I have placed the San Jose scale last because this insect, perhaps more than any other pest, provided the stimulus for certain far-reaching and world-wide developments in insect control and eradication.

*Chronology: Important Insects—Useful and Harmful.*—It may not have been preconcerted, but the first year of our Association came in with a bang, so far as useful and harmful insects are concerned. The first shipment of Vedalias was received at Los Angeles, California, in January, 1889—saving an industry and starting a new epoch in biological control.

This first year is notable also for the pioneer discovery by Theobald Smith of the Bureau of Animal Industry, of the blood-inhabiting protozoan cause of cattle fever in the South.

On the other side of the picture, this first year brought such new and important insect enemies from abroad as the horn fly and the gipsy moth—the latter new in that, after a fairly modest twenty years residence in the outskirts of Boston, it went on its first big rampage in 1889.

The following year (1890) witnessed the arrival in the District of Columbia of a considerable shipment of seedling date palms, which were to be not only the beginning of the date industry in California, Texas and Arizona, but unfortunately also of a struggle—still continuing—to control or exterminate two scale pests brought with these young seedling palms from Africa. One, the worst of these, is now practically exterminated, and the other pretty well under control.

Also in 1890, the Mediterranean fruit fly, from specimens submitted to the Entomological Division in Washington, was determined to be well established in Bermuda, where it was reported to be destroying the peach industry of the island. With respect to this new pest in nearby Bermuda—largely a popular resort for our eastern towns—it is of interest to note that the report of this invasion, while described as indicating danger to the "peach sections of the Southern States," and stating that "accidental entry . . . is always possible," makes no reference to quarantine or other protective measures!

In 1891 the Argentine ant was noted in New Orleans. It is now an important orchard and house pest in the South, and in California.

The San Jose scale was identified in Virginia in 1893, and this was followed by the determination that it was already widely scattered in the eastern states, Florida, and also in the Ohio and Mississippi Valleys.

In 1892 the Mexican cotton boll weevil was found to have invaded Southeastern Texas from Mexico.

In 1898, the brown tail moth was discovered in Massachusetts, having apparently been introduced by means of a shipment of roses from Europe a few years before.

The *Scutellista cyanea*, parasite of the larger soft scales, was successfully established in Louisiana and California in this year by Dr. Howard, in cooperation with

the Italian Station of Agricultural Entomology at Portici, Italy.

In the same year the Vedalia was sent to Portugal, Egypt, Madeira and Guatemala—the last two countries to control mealy bugs.

At the end of this decade, the fig fertilizing wasp (*Blastophaga grossorum*), was imported and established at Fresno, California—the attempt covering the last two years of this decade (1897–8) and completed in March, 1899, Dr. L. O. Howard, knowing that the fig groves and Capri figs in California were in full readiness for the insect, secured authority from the Secretary of Agriculture to undertake its introduction. At this juncture, he learned that Mr. W. T. Swingle, an agent of the Bureau of Plant Industry of the U. S. Department of Agriculture—a man well advised on fig fertilization—was in Europe, and he secured his services to collect and ship to him infested Capri figs. The first shipment (1898) failed to bring living insects; but the second, in March, 1899, resulted in establishing the insect in California. Two earlier attempts to introduce this insect, although they failed, well deserve record—the first in 1881 by Dr. Gustav Eisen of San Francisco, and the second, in 1892, by Mr. George C. Roeding of Fresno.

The final proof as to the insect vector (*Stegomyia fasciata*) of yellow fever, came at the end of this decade. (See Medical Entomology.)

As already indicated, elaboration of several of these subjects follows.

*Biological Control of Insect Pests.*—That biological control of insect pests might be artificially assisted by man had, according to Essig, its first definite record one hundred years ago (1840), in the use of *Calosoma sychophanta* by Boisgiraud, in France, to destroy the larvae of the gipsy moth. Many of you are familiar with the efforts in this field of various entomologists in the United States. Sufficient to say that most of these efforts failed, and none of them, prior to 1889, produced any notable results. It is of interest, therefore, that the year of the birth of this Association should witness the first epoch-making demonstration of man-made biological control. This followed the arrival in the United States January 24, 1889, of an Australian ladybird beetle, later identified as *Vedalia cardinalis*, and known in Australia to feed greedily on the cottony cushion scale.

In brief, the story of this beetle is as follows: the cottony cushion scale (*Icerya purchasi*), an emigrant to this country from Australia of about 1870, was by 1888 threatening the very existence of the citrus industry in California. Concerned in the epoch-making introduction of its enemy, the Vedalia, as it came to be known, were Riley, Crawford, Alexander Craw and others, and also our then Secretary of State, Thomas F. Bayard, who financed it out of funds granted him for representation of the United States at the Melbourne Exposition, but to Albert Koebele will go the major credit, as the collector and exporter, with recognition of D. W. Coquillett in California, as the recipient and expert handler and distributor.

Once established in the citrus groves of California, the Vedalia multiplied at an enormous rate, and its work was so effective that within three years (1892) the fluted scale was no longer considered a problem in that state.

This achievement of 100 per cent biological control—later extended by world-wide shipments of the beetle for the same or similar pests—was not only the first great success in this field, but still stands unequalled. The acclaim which greeted this achievement in California can well be understood. Biological control immediately took an exalted place, and became the first consideration with respect to all newly-introduced insect pests. This enthusiasm became in some quarters a cult, or almost a religion. Koebele himself came to believe—and his successes gave much to warrant to this belief—that with every such new pest, practically always with its natural controls left behind, there were available somewhere in the world the insect agencies which would bring it to a balance and would greatly reduce, if not stop, its harmful career. Elwood Cooper, the first Commissioner of Horticulture in California, whom I visited on his 20,000 acre fruit ranch about the middle of this decade, voiced his convictions to me in practically identical terms with Koebele. He added, with much feeling: "If I had the power, I would inflict the heaviest punishment on any person in the State spraying, gassing, or otherwise interfering

with such natural controls once introduced."

There is no time to discuss the other importations made by Koebele in connection with the cottony cushion scale, or with other scale pests in California, or his notable work in the same field in the Hawaiian Islands.

It remained for this adventure with the Vedalia to put biological control solidly on the map. With this record as incentive, members of the Association and others have carried forward biological control for the past fifty years, involving the collection of hundreds of different parasitic and predacious species from all quarters of the world, with the result of bringing the crop or forest pests concerned more and more into balance and under control.

*Insecticides.*—Before discussing the advances in the field of insecticides during the first decade, it may be helpful to list the principal insecticides then in use. These include pyrethrum, hellebore, whale oil and other soaps, emulsions of kerosene with milk and with soap, flowers of sulfur —wet or dry,—bisulfide of carbon, resin washes, cyanide gas, and lime sulfur and salt wash.

The arsenicals, paris green and london purple, were in wide use for leaf-eating insects, for the codling moth and for the potato beetle, paris green for thirty years or more. White arsenic was coming into the field, and in the season preceding our first annual meeting, Gillette—then in Iowa—had shown the possibility of greatly reducing leaf scald by the addition of lime to this arsenical and also to paris green and london purple. The arsenite of lime formula worked out by Taft and Kedzie of Michigan, came in the middle of this decade (1894).

A bran, arsenic, sugar bait for grasshoppers was devised and used in California in 1885. The importance of what is substantially the same bait for grasshopper control during the fifty years of this Association, warrants a brief note concernings its origin. The San Joaquin Valley was afflicted with a great scourge of grasshoppers in 1885. To meet this menace, the Superintendent of the Natoma Vineyard near Folsom originated a mixture of arsenic and sugar with middlings instead of bran. His success with this mixture became quickly known in the Valley, and the next extensive use of this bait was in the same season on the large properties of the Buhach Plantation, for the protection of its orchard and vineyard areas. Here bran was substituted for middlings, and has continued as the preferred carrier of the poison. Unfortunately, the name of this superintendent seems not to have been kept, but it certainly should be found so that the proper meed of credit may be given.

Time will not permit the mention of the many insect controls other than those commonly classed as insecticides which have been devised during the age-long period when man has been compelled to fight insects to maintain his food and comfort.

Turning now to the insecticide field in our first decade, the arsenicals paris green and london purple reached their maximum use in this period, and the other types of insecticides listed maintained fairly normal status. The important new developments were the use in the East of the lime sulfur salt wash, chiefly for San Jose scale, and the new insecticide arsenate of lead, developed early in the gipsy moth campaign in Massachusetts. The great importance of these two insecticides through our fifty year period warrants for each a brief statement.

Lime sulfur, long used as a fungicide, was employed against scale insects by Hubbard in 1884, as reported in his "Insects Affecting the Orange," submitted March, 1885. Elwood Cooper, President of the California State Board of Horticulture, in his report for 1885–6 (published 1887) recommended a similar lime sulfur spray. The Australian sheep dip, a combination of lime, sulfur and salt, was introduced into California for that purpose in 1885–6 by A. T. Covell. The first use of this mixture for San Jose scale, according to Essig, was by F. Dusey of Fresno, in 1886, who had obtained for this purpose a supply from Covell. The success obtained with this wash quickly led to its general adoption in California as a dormant-tree wash for this scale. The year following the discovery (August, 1893) of the San Jose scale in Virginia, this wash was used in infested orchards by the writer, but with not very satisfactory results—possibly due to following rains. Later, after personal studies in California, additional tests were made in Washington

with the mixture very fully boiled—some three hours—and applied while hot. The results were very satisfactory, and the use of the wash became general in the East, the salt ingredient soon being omitted as of no benefit. This wash very largely solved the San Jose scale problem for the East, as it had on the Pacific Coast, and this, together with the additional protection it gave as a fungicide, warrants its designation as the outstanding insecticide of this decade.

*Arsenate of Lead*, the other rival for high honors of the decade, emerged, as already indicated, early in the battle against the gipsy moth—paris green and london purple having proved, in the work directed by Fernald, of little value against the caterpillars, especially in their later stages. In a discussion of substitute poisons at a hearing before a Committee of the Massachusetts State Legislature, arsenate of soda was proposed by A. H. Ward (winter, 1892–3). This arsenate, entirely soluble in water, injured the foliage to such an extent as to prohibit its use. Dr. Fernald then requested one of his Field Agents, who had had a training in chemistry—Mr. F. C. Moulton, to find some material which would precipitate the arsenate of soda, in an attempt to remove its causticity. Moulton suggested a combination with acetate of lead, and then carrying out his idea, produced arsenate of lead. This compound, under experiments by Fernald, proved to have very distinct advantages over the old arsenicals—viz., complete insolubility in water, eliminating leaf scald; fineness of division, therefore holding well in suspension; and evenness of distribution on foliage. This new chemical became at once the standard poison in gipsy moth work. Its adoption for other pests did not, however, become extensive until toward the end of this decade, but very soon thereafter it practically supplanted the older arsenicals for leaf-feeding insects, including the codling moth.

*Creosote Oil.* Another important outcome of the gipsy moth work of this period was the discovery that a cheap grade of creosote oil, daubed on the egg masses, gave practically 100 per cent kill. Fernald credits the suggestion of this oil to Prof. N. S. Schaler, Geologist of Harvard University. Its employment began in the winter of 1891–2, and it has continued to be a very important factor in gipsy moth control, notably in outlying points of infestation.

The origin and preliminary development of the use of *hydrocyanic acid gas* against citrus scale insects by D. W. Coquillett, an agent of the Division of Entomology, preceded by some two years the founding of our Association, and therefore this poison is listed as available prior to 1889. Its standardizing in orchard practice, however, was continued in California under Coquillett until 1894, when all field agents of the Division were discontinued or called to Washington. Coquillett's work with this gas was thus completed well within the first decade, and when we consider the present wide range of the insecticidal use of this gas, we would be fully warranted in recognizing it as the outstanding insecticide of the fifty year period.

MEDICAL ENTOMOLOGY.—You are familiar with Dr. Howard's interest in Medical Entomology, and of his efforts to give every possible aid from the entomological angle to medical experts in their attempts to solve various important diseases believed to be insect-borne.

As already noted the great event in this field for the United States and the world was the pioneer discovery by Theobald Smith in the opening year of this decade, of a blood-inhabiting protozoan and its relation to its double hosts—the cattle tick and cattle in the South—as the cause of Texas, or southern, cattle fever.

The determination of the relation of insects to malaria and yellow fever followed this epoch-making discovery, and the insect vectors of these diseases made entomological cooperation even more necessary. With respect to yellow fever, for three hundred years the great scourge of sub-tropical and tropical America, the last year of this decade was to witness the final proof—long suspected—that the mosquito (*Stegomyia fasciata*), world wide in distribution, was the insect vector of the disease.

This proof was obtained by a commission (1898–1901) appointed by Surgeon General George M. Sternberg, consisting of Doctors Walter Reed, Jesse W. Lazear and J. C. Carroll of the U. S. Army, and Dr. A. Agramonte, a Cuban physician.

You will recall that these men jeopardized their lives in this work by taking the disease through bites of infected mosquitoes, costing the life of one of them—Dr. Lazear. This determination, and the controls based upon it, made it possible practically to stamp out yellow fever from the tropical and sub-tropical areas of the world where it occurred. Dr. Howard collaborated in supplying full information on the distribution, biology and control of the mosquito.

The cooperation of the Federal Bureau in the field of Medical Entomology has been continued, as to the insects concerned, in these and other protozoan diseases, through our fifty year period, as an important subject of the Bureau's Division of Insects Affecting Man and Animals.

*The Gipsy Moth.*—It is interesting to recall that this insect is mentioned by Riley in his Second Missouri Report (1870, page 10) as follows: "Only a year ago the larva of a certain owlet-moth (*Hypogymna dispar*), which is a great pest in Europe, both to fruit-trees and forest-trees, was accidentally introduced by a Massachusetts entomologist into New England, where it is spreading with great rapidity." (The "entomologist" was of the type who believed it would be possible to create a hybrid gipsy moth that would become a source of silk in the forests of Middlesex Fells! The truth is that he was a French professor of astronomy at Harvard!) Following its first alarming outbreak in 1889, Riley opens an article in "Insect Life" on the gipsy moth in the following language:

> "This conspicuous insect, although not recorded in any of our check-lists of North American Lepidoptera, has undoubtedly been present in a restricted locality in Massachusetts for about twenty years. It was imported by Mr. L. Trouvelot in the course of his experiments with silk-worms recorded in the early volumes of the *American Naturalist*, and certain of the moths escaping, he announced the fact publicly, and we mentioned it in the second volume of the *American Entomologist*, p. 111, (1870) and in our second report on the insects of Missouri, p. 10."

As a result of the outbreak in 1889, the Legislature of the State of Massachusetts, (March 14, 1890), established a Gipsy Moth Commission and made an appropriation of $25,000 to undertake eradication. With increasing cost and with minor interruptions, this effort, emerging from eradication to control, has continued to the present time. Up to 1895 the state expenditures exceeded $500,000, and by the end of our first decade had reached a total of a million dollars—with perhaps an equal expenditure by residential property owners.

No effort was made by the state in this decade to introduce foreign insect parasites and predacious enemies for the reason that, the object being prompt extermination, such enemies would be of little or no help. Also no Federal aid was requested by Massachusetts, nor was any such aid granted, until well along in the following decade. Naturally the Federal Division of Entomology was very much interested in the work, and cooperated to the extent of occasional surveys, in which also various state entomologists participated, with the result that the methods being followed by the state received general approval. Full credit belongs, therefore, to the state officials for the work in this decade, and for the means and methods developed thereunder. Two new insecticides—one of the highest importance—were developed early in the gipsy moth work. These are discussed in my section on *Insecticides.*

This was the first great effort in this country to eradicate a well established insect pest, and while not successful—the work having been discontinued by the state for an interval of several years—it at least indicated a reasonable possibility of eradication.

In view of the continuance and increasing importance of this problem through our fifty year period, it is interesting to note the very hopeful attitude taken at its inception in an editorial in *Insect Life* of January, 1890, reading as follows:

> "In conclusion we may state that if Prof. Fernald's recommendations are carried out at all strictly, we have little fear of the spread of this pest, and agree with him that it can be entirely killed out with the expenditure of a little time and money."

The recommendations were "spraying all trees in the infested region with paris green, soon after the hatching of the eggs in the spring, for two or three years under competent direction."

*Cotton Boll Weevil.*—The entry into Texas of the Mexican cotton boll weevil was discovered in 1894—the sixth year of our decade. That this insect occurred in

Mexico and was there very destructive to cotton, was brought to Dr. C. V. Riley's attention some nine years earlier (1885) by Dr. Palmer, a biological explorer, who had been working for some time in Mexico. Dr. Palmer reported that the depredations of the insect had led to the abandonment of cotton at various points in that country, and particularly in the neighborhood of Monclova, opposite to, and not far from, Laredo, Texas. Dr. Riley published this information in his annual report for that year, but did not mention, and probably had no thought of, a quarantine to prevent the entry of this new pest into the United States. In fact at that time, quarantine consciousness seemed not to have developed in the United States outside of California! This insect made its entry into Texas at Matamoros, near the mouth of the Rio Grande and, when reported, had already advanced along the Gulf and northward. By the end of the decade it had reached San Antonio, and covered a fan-shaped area southward to the Gulf. Here again, from our present outlook, it seems extraordinary that there was no immediate discussion of the possibility of eradication under state and federal action, which certainly now would be the first thought. Instead, a letter was sent by the Assistant Secretary of Agriculture to the Governor of Texas, urging the importance of a state quarantine to prevent the spread of the weevil in Texas, and the enforcement of remedial work! No action followed.

During this decade the division was given no special funds to aid in boll weevil control, and little more could be done than to determine the spread of the insect, work out its biology, and make a preliminary study of means of control. I may infringe a little by saying that the first Federal appropriation ($250,000) with respect to this insect was in 1903—of which, however, only $20,000 was assigned to the Division of Entomology—the Bureau of Plant Industry, having a program already worked out, received the bulk of the fund!

*The San Jose Scale.*—The identification of the San Jose scale in Virginia in 1893 was followed by the discovery that it was already widely scattered in the eastern States, in Florida, and also in the Ohio and Mississippi Valleys. This alarming situation, together with the evidence that this scale actually poisoned and often killed fruit trees, made it the major insect pest of this decade. Its control in the East, following preliminary experiments with hydrocyanic acid gas and the soap-oil washes, etc., was in the use of the lime sulfur wash as a winter or early spring application.

Historically, ornamental nursery stock, (flowering peach), brought this scale from North China to California. Early in this decade, nursery stock carried it to a nursery in Missouri and to others in New Jersey. Its widely scattered points of infestation, determined in 1893 and shortly thereafter, came, unwittingly, from sales of infested stock by these nurseries.

Time may perhaps be allowed to consider certain national results as to this country, and also world wide consequences chargeable to this insect. I have in mind the development of what may be called plant quarantine consciousness—state and national—in this country and also in many foreign countries which, like ourselves, had been laggards in this field.

Beginning at home, it is not news that California was the pioneer in such protective action, but it may not be known that this interest dates from the year 1880, when the San Jose scale had reached the height of its damage in an important section of the State. In 1881, California established an Advisory Board of Horticulture with power to enforce control within the state, and in 1883 a State Horticultural Commission was created and a plant quarantine enacted, covering entry into the state, from both foreign and domestic sources, of plants and fruits. This legislation, on the authority of B. F. LeLong, Secretary of the California State Board of Horticulture, resulted from the demand for protection from introduced pests by the aroused fruit growers of the state—and in his list of such pests, the San Jose scale has first place.

Incited by the San Jose scale again, Dr. Howard, in an editorial note in *Insect Life* referring to the laws of California, New Zealand and Australia, urges the state legislators to follow the example of California and these foreign countries in the enactment of laws giving

authority to prevent entry, and to effect control or extermination of new insect pests. Later, in *Insect Life* it is noted that such laws had been proposed by the States of New Jersey and Massachusetts, and action by other states followed. No suggestion is made, however, of federal action; but as to this it should be noted that such action then, as now, calls for an invasion of "state rights"—a very deterrent factor!

Shortly afterwards, however, a nation-wide attempt was made to secure a Federal law. In March, 1897, a convention initiated by the Ohio Horticultural Society was called in Washington with the object of drafting legislation covering both interstate commerce in, and foreign entry of, plants and fruits—the attendance consisting of horticulturalists, entomologists and nurserymen. At this convention resolutions were adopted urging state action, chiefly for internal control, and a Federal bill was drafted covering both state and foreign commerce in these articles. This bill was duly entered in Congress, but having no very keen follow-up, dragged along without making any progress until 1908, when a new and very different bill was submitted to Congress, which, after a stormy voyage of four years, became the Plant Quarantine Act of 1912.

As already indicated, foreign interest in the San Jose scale became strongly aroused in the last years of this decade, resulting in the enactment of quarantines against the entry of our plants and fruits by some nine foreign countries, and most other countries having important commerce with the United States followed shortly thereafter.

This record would seem to justify the statement which I made in a presidential address before this body following the close of this decade—namely, that the San Jose scale has aroused more interest and attention throughout the world than any other insect problem which has arisen since the dawn of history!

It is worth re-emphasizing that "quarantine consciousness" traces, first in California and much later in middle and eastern United States, to the San Jose scale. This should be some offset to our usual thought of this scale, named by Comstock in 1880, "*perniciosus.*"

THE SIGNIFICANT THING OF THE DECADE.—In conclusion, and taking an outside view of the achievements of this, the first decade of our Association, in my judgment the thing of the greatest significance to the future of applied entomology is not the major new pests which have been stressed in this paper, nor the new means devised in this period against these and other harmful insects, but it is rather the mental attitude which became general towards the end of the decade, which I have referred to as "quarantine consciousness" and "eradication consciousness," in the face of the threat of entry of a new and dangerous pest, or when confronted with the much greater emergency of such pests already strongly established in our midst. I think none of us will question that if this attitude of mind had been aroused a little earlier, the Mexican bean beetle and the Mexican cotton boll weevil might have been excluded, or on entry both of these pests might have been eradicated or their spread greatly retarded. At least we could have made a good fight, as we did later, and with success, with the pink boll worm and the Mediterranean fruit fly.

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# Fifty Years of Entomological Progress, Part II, 1899 to 1909

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Before beginning to read my paper I wish to thank the committee which chose the speakers for the generosity and thoughtfulness which prompted them to ask a Canadian to deal with one decade, especially when they knew that there were many Americans much better qualified. I take it for granted that I was chosen not because of any special qualification, but because they mistakenly thought I had been in active service longer than any other Canadian.

In preparing my part I have felt myself handicapped by the fact that I began

entomological work only in 1908 and therefore had just one year of experience in the period allotted to me. Hence I have had to try to visualize the progress made almost solely from reading the available literature.

In discussing the development of entomology between the years 1899 and 1909, it is helpful to keep in mind that there is no dividing line between this and the preceding decade, for all the great new problems of the first such as the gypsy moth, the San Jose scale, and the cotton boll weevil, were still great problems in the second. Moreover almost all the great leaders and teachers of the first period—Dr. L. O. Howard, Dr. J. H. Comstock, Dr. C. L. Marlatt, Dr. C. H. Fernald, Dr. S. A. Forbes, Dr. Herbert Osborn, Prof. J. B. Smith, Dr. Jas. Fletcher, Prof. Lawrence Bruner and several others—were still alive, actively at work, and capable of accomplishing even greater things than before because of their widened experience and broadened vision.

Progress in entomology depends to a large extent upon the academic training given to those entering upon it. The training of men to be professional entomologists began only about the year 1889, yet by the end of the first decade it had made remarkable progress and this progress continued all through the second decade. By 1909 the curricula of several of the colleges, notably Cornell, were so far advanced that they would be considered good even for today. Dr. Comstock, Dr. Forbes, Dr. Osborn and most, if not all, of the other leading teachers were themselves active research workers and from their own experience realized what was necessary to prepare students for research. Consequently great stress was laid upon the careful study in the laboratory of morphology, physiology and development of insects, as well as upon technique, classification, life histories and control. Accuracy in all these was emphasized as essential for success. In addition to entomology the students in the best institutions were required to have a fair knowledge of some of the closely related sciences—botany, zoology and chemistry. Dr. Forbes as early as 1908 urged that ecology and statistical methods should also be added to the curriculum. During the decade the number of teachers on the different staffs at least doubled. This made possible a division of labor and the addition in several of the colleges of graduate work leading to a master's or doctor's degree.

As to students, the need of men for the Experimental Stations and for the Bureau of Entomology along with the growing popularity of entomology led a great many to choose entomology as their option, so that there were apparently sufficient graduates to supply or nearly supply the demand. As progress in entomology is made easier and more rapid by increasing the number of men actively engaged in the science, it is interesting to know that Dr. L. O. Howard said that he was of the opinion that there were not 28 qualified entomologists in the whole of the United States in 1894. Yet we find that so great had been the increase that by 1909 there were almost 100 graduates in the Bureau of Entomology alone and nearly as many more employed by the different states. Moreover, appropriations for the wages of these men and for other entomological expenses had also increased very rapidly: for instance, the federal appropriation in 1899 was $29,500. and in 1909 was $424,960. State appropriations also had increased greatly. Therefore, so far as men and money went, there was good provision for progress.

IMPORTANT ADVANCES.—I wish now to try to point out some of the more important advances made in the field of economic entomology during the decade. The most outstanding came from the fight against the gipsy moth, the San Jose scale, the cotton boll weevil, yellow fever, malaria, typhoid and Texas fever, and from the study on a vast scale of the forest insects of the nation.

**The gipsy moth,** which in the previous decade had been brought under good control, had, as a result of the failure in 1900 of the State of Massachusetts to vote funds for further control, become so abundant and widespread by 1905 that the Federal Government had to come to the aid of the State with many men and large appropriations. From the ensuing campaign up to 1909 came the following valuable results:—

1. Even though strenuous efforts did not prevent the moth from continuing to do great damage and spreading, they did prevent its doing much greater damage and spreading much farther and wider,

and laid the foundation for future control.

2. It developed good systematic methods of fighting forest insects of this type on a large scale.

3. It led to a much clearer and better division of responsibility for the control of imported insects between the Federal and State Departments of Agriculture and therefore to much more effective cooperation—a matter of great importance henceforth to the nation.

4. It demonstrated very forcibly the damage that an introduced forest insect can do when it finds the environment favorable and therefore, along with the San Jose scale, the cotton boll weevil, and other foreign pests, led to a great agitation for safeguards against the importation of any more foreign enemies. This, in the next decade, resulted in the establishment of the Federal Horticultural Board and Division of Plant Quarantine—a step which has been of inestimable value to the nation.

5. It led logically to the greatest experiment the world has ever seen in biological control. Whether or not this experiment ultimately results, as hoped, in bringing about a full or partial equilibrium of the insect with its environment, it at least will have been of immense value through the knowledge and experience gained in carrying it out.

**The San Jose scale,** the second great problem, contributed to progress chiefly in the following ways:—

1. It brought about great advances in spraying because, out of the many insecticides tested against it, lime sulfur was widely adopted by the end of the decade as the standard remedy. This was quickly followed by the use of a concentrated form of the wash which was soon found to control also the oyster shell scale and blister mite and to be so good an orchard fungicide that it to a large extent displaced Bordeaux mixture for fruit diseases. At the same time arsenate of lead came to be generally accepted as the most satisfactory stomach poison; so that now we had an excellent insecticide and also an excellent fungicide for orchards. Moreover the great need at this time of thoroughness in spraying and of lessening the amount of manual labor had gradually led to the displacement of hand sprayers by power sprayers equipped with cyclone nozzles. Thus with safe, effective, and inexpensive spray mixtures and a rapid, much easier, and more efficient means of applying them, spraying became much more popular and fruit growers were able to produce better, cleaner, and more fruit than ever before. Spraying now became the most valuable factor in successful fruit growing.

2. It led to a very thorough study of hydrocyanic acid gas and its uses, as the result of which most of what we know today about this gas was learned. This enabled the growers of California and Florida to substitute it for sprays against scale insects and white flies on hundreds of thousands of acres of citrus and other trees. It also made possible its safe use on nursery stock, in greenhouses, flour mills, ships, and even private homes.

**The cotton boll weevil,** by 1899 had become so abundant and caused so great damage—about $25,000,000 a year—to cotton fields that it was clearly seen that, if no effective control could be devised, the growing of cotton would soon have to be abandoned. This would have meant bankruptcy and indescribable suffering to the South, for cotton was their great crop and the source of by far the greater part of their income. Under these conditions the Bureau of Entomology, in 1901, began one of the best planned and most extensive investigations of all time and carried it out just as thoroughly as it had been planned. Before the end of the decade so much progress had been made that Dr. W. D. Hunter and Dr. W. E. Hinds were able to demonstrate on a large scale to the growers that by adopting certain cultural practices, especially planting early maturing varieties and harvesting the same early in the fall and destroying all stalks and remnants, the South could continue indefinitely to grow cotton at a profit in spite of the weevil. This discovery gave hope and courage to the farmers and at the same time gradually brought about much better and more diversified methods of farming in the affected areas.

The thoroughness of the investigation also helped greatly in the way of progress by serving as a great example and inspiration to other entomologists to plan and carry out their investigations with greater care, and especially to take into account more fully than before climatic

and all other environmental factors; for it was largely by close attention to these that it had been possible to work out the control.

FOREST INSECTS.—The study of forest insects as a National or even as a State problem had received relatively little attention until Dr. L. O. Howard assigned the task to Dr. A. D. Hopkins in 1900. The latter at once threw himself whole-heartedly into the subject and though his studies had not been completed by the end of the decade, he had made such remarkable progress that by 1909 he had discovered the chief insects responsible for most of the outbreaks, worked out numerous life histories of these, studied their habits and the factors that caused their increase or decrease, and had published a large bulletin on "Bark Beetles of the Genus Dendroctonus." As a result of his studies he was able to work out and demonstrate practical methods of controlling and preventing outbreaks, especially of bark beetles. These methods consisted chiefly in so changing the system of forest management, lumbering and manufacturing that instead of its favoring the insects it would destroy them. His work has meant a great increase in our knowledge of forest insects and their control and has led to better protection of the nation's forests—one of its greatest assets.

MEDICAL ENTOMOLOGY.—In no aspect of entomology, however, was greater progress made during the period 1899 to 1909 than in medical entomology. It is true that in the case of yellow fever and of malaria most of the work was done by medical men, but that makes little difference so long as the discoveries were made and the results were helpful to the public and to the advancement of entomology.

In 1901 it was definitely proven and accepted that yellow fever was carried by means of a mosquito, *Stegomyia calopus* (*Aedes aegypti* Linn.). Almost as soon as this fact was learned, vigorous steps were taken to destroy the breeding places of the insect and to isolate all fever patients from mosquitoes. The work was carried out under the supervision of the Public Health and Marine Hospital Service and was done so thoroughly that in 1905 the last real epidemic of yellow fever in the United States took place in New Orleans. Since then, so far as yellow fever goes, it has been practically as safe to live in New Orleans as in Rochester or Toronto.

Malaria, though not so deadly a disease as yellow fever, was very much more common at that time. Dr. Howard estimated that 3,000,000 persons were attacked by it annually in the United States with a mortality of about 12,000. The disease greatly enfeebles children and adults who contract it, even though they do not succumb. It was especially prevalent in the South and kept millions of acres of rich land in the Mississippi Delta almost unpopulated for years. The total loss from it to the nation was estimated at $100,000,000 a year.

That this disease was carried only by mosquitoes of the genus *Anopheles* had been discovered in India in 1898 by Major Ross. Almost at once medical men and entomologists, influenced by what had been done already, took up the work in this country of stamping out malaria by destroying the breeding places of the mosquitoes and protecting people from being bitten at night by screening homes and other sleeping places. Beneficial results came rapidly and have continued to do so up to the present day when malaria has very largely disappeared over most of the United States and Canada. An outstanding example of the success of the measures against both malaria and yellow fever was the building of the Panama Canal with very few deaths from either disease.

Typhoid fever was another very common and dangerous disease spread to a large extent, though by no means solely, by insects. It was not until this decade that the house fly was proven by the investigations of Dr. Howard and others to be the great insect carrier of typhoid and that present methods of control were worked out. Dr. Howard, Dr. Forbes, Dr. Felt, and many others devoted a great deal of time to proclaiming far and wide the need of destroying the breeding places of the fly and of protecting our milk and food from contamination by it. A great deal of work by scores of entomologists was given to investigations on the best ways of doing these things. The result was that many people in every state and in Canada have learned to regard the house fly as a great menace and to adopt the necessary measures to protect themselves and their families against the danger of

typhoid or other diseases carried by the fly.

The Texas fever of cattle was another of the great pests studied during the first and second decades. The disease, wherever present, caused many cattle to die and enfeebled the remainder to so great an extent that successful cattle raising, either for beef or for dairying, was impossible and often even the supply of milk for the nourishment of children was lacking. Hence the southern states, where it prevailed, had not only the cotton boll weevil but also this pest to hamper them, with the result that the outlook was gloomy indeed. The annual loss from Texas fever was estimated at $100,000,000.

In 1892 it had been discovered that the Texas tick, *Margaropus annulatus* Say, was the sole carrier of the disease. Accordingly, work soon began on the study of the tick in the hope of control or possible extermination. A great deal of this work was done in the first decade but it was much further advanced between 1905 and 1907 by the studies of W. D. Hunter and W. A. Hooker of the Bureau of Entomology. By 1907, as a result of their careful investigation of the habits and life history of the pest, a method was found of freeing large areas by careful attention to rotation of pastures. The importance of quarantine to prevent further spread was also recognized and pointed out. It remained, however, for the next decade to work out fully a method of control so satisfactory that the tick has now not only been checked but totally eradicated from most of the South and will probably in a few years be annihilated in the United States. How great a boon this will be to the South only those who have lived there can tell.

The above is a very brief story of a series of remarkable achievements which have brought inestimable blessings not only to the states most concerned but also to the whole nation. It is not, however, the full story, for while the Federal services took the leading part in the above, almost every state in the Union was contributing something and several of the larger or wealthier states a great deal. There is not time to go into details so I shall merely mention a dozen or so of the problems on which decided progress was made by the states—namely, biological control (in California), apiculture, grape phylloxera, white grubs, corn root aphis, Hessian fly, chinch bug, San Jose scale, codling moth, plum curculio, orchard aphids, grape leaf hopper, blister mite, and cabbage and onion maggots.

EXTENSION.—So far I have dealt almost exclusively with teaching and research, but there is another very important side of economic entomology, namely, extension, or inducing the farmers to make use of the control measures definitely proven to be effective against injurious insects. There is very little in the literature to show what progress was made along this line, but evidently all progressive fruit growers were now spraying and in case of outbreaks farmers freely sought the assistance of entomologists. Yet it is probable that extension work in this decade, though it made progress, did not keep pace with research. It is only fair to mention here that horticulturists cooperated heartily in the extension work as chemists had done in finding effective insecticides.

I should have liked very much if there were time to speak also of the part played by the Association of Economic Entomologists, the Entomological Society of America, and the periodicals of these and other societies, for we all know that they have been of very great value to every entomologist.

I should also have liked to be able to point out the very valuable contributions to entomology during the period by taxonomists, morphologists and physiologists, such as W. H. Ashmead, J. M. Aldrich, H. G. Dyar, Nathan Banks, W. M. Wheeler, T. D. A. Cockerell, D. W. Coquillett, E. P. Van Duzee, A. D. MacGillivray, V. L. Kellogg, August Busck, J. W. Folsom, and a score or more others.

PROGRESS IN CANADA.—But I must conclude with a few paragraphs on the progress of entomology in Canada. In Canada progress was unquestionably much slower and less spectacular than in the United States, but this, I believe, may be accounted for in two ways: first, with the exception of the San Jose scale which, by the way, was limited to a comparatively small part of the single province of Ontario, Canadians did not have to face any new terrible insects such as those which the United States had to face and which were largely responsible for the

rapid progress of entomology in that nation; and second, Canada had fewer insect pests and those that were common to both countries were, I feel sure, on the average less numerous and less destructive than in your country. Hence Canadians had not the insect conditions which induce governments to grant appropriations and appoint entomologists in sufficient numbers to meet them and make rapid progress possible.

Economic entomology in Canada during this decade centered largely around Dr. James Fletcher, Dominion Entomologist and Botanist, and the Ontario Agricultural College at Guelph. Dr. Fletcher, although he had only two assistants, Mr. J. A. Guignald and Mr. Arthur Gibson, did an enormous amount of work. Professor J. B. Smith said, "He carried a burden that can never again be imposed upon any one man." By his public addresses, writings, visits, and other services, he aroused so much interest in insects and their control that he was largely responsible for the rapid progress in entomology made soon after his death, which occurred in 1908. He was remarkably well acquainted with all the discoveries and advances made in the United States and at the same time managed to do a good deal of experimenting and testing of recommended control measures to satisfy himself of their efficacy. When the San Jose scale arrived, he took a leading part in the fight against it and had much to do with bringing about the passage of the Federal San Jose Scale Act, which prohibited the importation of plants from infested areas and led to the appropriation of sufficient funds to pay for inspectors to enforce it. His annual reports of his work and a very valuable bulletin on "Insects Injurious to Grain and Fodder Crops, Root Crops and Vegetables" have been of much assistance to later Canadian entomologists.

The Ontario Agricultural College's contribution during the period was chiefly along the line of teaching. A series of lectures on the common injurious insects of the farm, orchard and garden was given to all students of agriculture and in addition there was a joint course for entomologists and botanists leading to a bachelor's degree. The great majority of the Canadian entomologists and likewise several American entomologists were trained at Guelph. Towards the end of the decade Macdonald College, near Montreal, was founded and similar courses in entomology given there. Some instruction, chiefly economic, was also given to students at the Agricultural School at Truro, Nova Scotia, and a little in one or more of the western provinces.

The head of the Department of Biology at the Ontario Agricultural College through most of the decade was Professor Wm. Lochhead. He was succeeded for one year by Professor Franklin Sherman, Jr., and he in turn by Dr. C. J. S. Bethune. During all this period these men and their entomological assistant, Mr. T. D. Jarvis, acted in much the same capacity as several of your state entomologists and tried to keep in close touch with the insect problems of the province and give leadership as far as possible by helping in the fight against the San Jose scale and outbreaks of other insects and by persuading the Provincial Legislature to pass an act requiring the inspection and fumigation of nurseries and the inspection and compulsory spraying of orchards for the scale. Unfortunately, college duties were so heavy that they had not nearly sufficient time to do half of what they saw was needed. When I was appointed as assistant in 1908, I was the first entomologist of the province to be able to spend most of my time on investigation and extension work. I was surprised to find that at that early date nearly all the fruit growers in the Niagara district and many in other parts of the province were spraying their orchards for insects and diseases and had adopted lime sulfur as the best remedy for San Jose scale. Power outfits were also fairly common throughout the province and a few had been used as early as 1904. In Nova Scotia similar progress in spraying had also been made. So even though progress in Canada was slow, yet very considerable progress had been made.

During all this period the Entomological Society of Ontario had been bringing together both economic and systematic entomologists in valuable annual conferences and the *Annual Report* of the Society made the papers and discussions available to all entomologists and also to many fruit growers in Canada. The Quebec Society for the Protection of Plants was founded in 1908 and it along

with its published proceedings helped in the same way.

Before taking my seat I should like to acknowledge the debt of gratitude that we as Canadians owe to the entomologists of the United States for the great assistance they have always so readily given us whenever we have asked for it, and we have asked many times. Nothing has contributed more to the progress of entomology in Canada in the last fifty years than our proximity to the great friendly, progressive nation along our southern border. We thank you for the favors received and hope that from now on we in turn may be able to contribute something worth while to you in the same friendly, unselfish manner.

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# Fifty Years of Entomological Progress, Part III, 1909 to 1919

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To attempt to review in thirty minutes the significant trends and accomplishments of American entomologists for a decade is indeed a task to make one wish for some method of speeding up the mental processes to the tempo of modern radio transmission. It is impossible to do justice to the subject. All one can hope to do is to expose some of the causes underlying the trends and intensifications in particular areas of entomological progress and to cite some of the most far-reaching discoveries, and a few of the most influential persons and their spheres of influence in this particular decade.

THE WORLD WAR.—A unique, and possibly the most powerful factor affecting developments during this decade was the first World War, which burst upon this period, subjecting entomology, as everything else, to tests and trials not previously experienced since entomology had become a science.

The emergency caused by a simultaneous diminution of production, and a greatly increased demand for cereals and other food crops, brought to the attention of the world the important part played by crop-destroying insects, as probably no other circumstance could have done. The sugar shortage due to war intensified honey production and led to the production and export of about $2,000,000 worth of this product in 1918—ten times the amount in any previous year. There was a vast increase in our knowledge of the honey bee itself, important investigations of foul-brood diseases, the first artificial insemination of queen bees, and many other important developments in apiculture, both in the federal government and in many of the states.

The war greatly stimulated efforts to suppress insects affecting stored food supplies and clothing intended for overseas shipment. Damage by powder post beetles to army and navy stores of tent poles, oars, aircraft parts, implement handles, and other articles of war-time necessity, revealed the need for more effective control of these pests. Even such moderately important pests as the locust borer and the insects destructive to mesquite took on general significance, because the black locust made the best pins for wooden ships and the mesquite was used extensively for fuel at army cantonments.

With the lessons of all previous wars plainly recorded, entomologists were not slow to realize that disease-transmitting insects might easily become a determining factor in the struggle. Flies, mosquitoes, lice, and bedbugs received more attention than ever before and elaborate tabulations of other insects related to the health of man and animals were placed at the service of the War Department. A small number of entomological experts were assigned to sanitary work in the army. The testing of control measures for pests of this class contributed to the solution of problems of camp sanitation; delousing methods were perfected which were used at the front and, at the close of the war, for all troops returning from the war area.

The necessity of reducing the amount of arsenic used in controlling insects, because of its consumption in the manufacture of munitions, was a stimulus to the search for other insecticides, especially

substitutes for lead arsenate, the price of which became prohibitive.

The necessity for increased food production and conservation was an enormous stimulus to extension work. The war emergency entomological intelligence service, organized to reveal day by day any undue increase or outbreak of any insect pest anywhere in the United States, greatly aided in the control of crop pests and an increase in food production. It demonstrated a permanent need for such information, and a modification of it is in operation today as the Insect Pest Survey.

While the war doubtless did much to establish entomology in this decade as a great and necessary science, contributing directly to human welfare, it must be recorded that the aftermath of the war later brought about an entomological depression, greatly reduced appropriations for scientific work with tremendous curtailment of opportunities for employment in this field, from which we have not yet fully recovered. This in turn has stimulated an intensification of training and competition for the few available jobs, which may yet in its turn react to the great benefit of our science.

FOREIGN INVADERS.—Perhaps the second great factor affecting the development of entomology from 1909 to 1919 was the succession of foreign pests which invaded our country from abroad during this period, or were first revealed during this time. In rapid and almost overwhelming sequence came the alfalfa caterpillar, first noted as a pest in 1910; the European earwig, discovered in Oregon (1909), in Rhode Island (1911), and in New York (1912); *Hypoderma bovis*, first revealed in North America in 1912; the Japanese beetle, discovered in New Jersey in 1916; the Oriental fruit moth, found near Washington in the fall of the same year; the pink bollworm, which gained a foothold in Texas in 1917; the European corn borer, first recognized in Massachusetts in the late summer of 1917. The Surinam cockroach was reported from Connecticut greenhouses in the spring of 1917. The sweetpotato weevil was intercepted in shipments from China to San Francisco as early as 1913 and became established in America at least by 1918. There was also the introduction of the vegetable weevil into California, the pea moth into Wisconsin, and the tropical fowl mite, European pine shoot moth, the European pine sawfly, the pear thrips, and certain bulb flies. The cotton boll weevil spread over about the eastern half of the cotton belt during this period. Although much of the distress and panic due to its invasion had already subsided, its control by poisoning the condensation droplets which it drinks, with lead or calcium arsenate, was developed and widely adopted, during this decade.

The crises presented by these pests brought about the first tremendous appropriations for the study and control of major pests on a large scale and the organization of the most gigantic and expensive campaigns against particular pests ever undertaken in any country. For better or for worse, we must admit, I believe, that these foreign pests first made the great majority of the American people, in all walks of life, *insect-conscious*. "corn borer," "Japanese beetle," and "peach moth" became household words, familiar alike to farmer, housekeeper, politician, butcher, baker and banker. The American press likewise caught the trend, and the mention of insects in the daily papers, farm journals, and all other kinds of general publications, ceased to be a rarity to be talked about and marveled at.

Among secondary factors influencing our growth at this time were the rapid development of the automobile and the airplane, which greatly accelerated the spread of insect pests; the adaptation of motion pictures in teaching and extension work; and great improvements in optical equipment particularly the wide-field, erect-image, binocular microscope.

MOST IMPORTANT ECONOMIC INSECTS.—The economic problems which may be said to have held the center of the stage during this period include: the gypsy moth, with intensive studies of its feeding habits, dispersion and natural enemies. A degree of triumph in the conquest over the cotton boll weevil. The Dendroctonus beetles of our forests. The codling moth, especially studies of its life cycle in various areas. The honey bee as a food-producing animal. The control of the alfalfa weevil, which expanded ominously in the Rocky Mountain states. A study of the "broods" of the white grubs. Great advances in our knowledge of the habits and

life cycles of ox warbles and horse bots. Clarification of the apple aphid complex, including the identity of various species, the discovery of their alternate hosts, and an effective control by delayed-dormant sprays. The conquering of the peach borer. The first study of the biology of the spruce budworm in Canada where a serious outbreak began, which is said to have resulted in the destruction of 200 million cords of pulpwood. Outbreaks of the green bug, grasshoppers, potato aphid, armyworm, and fall armyworm.

Other pests receiving extended consideration during this 10-year period were: grape, cranberry, sugarcane, and pecan insects, red spider mites, the wheat jointworm, corn rootworms, tobacco hornworms, malarial mosquitoes, the house fly, the stable fly, the spotted fever tick, the Hessian fly, the hickory bark beetle, the beet leafhopper, the range caterpillar, and insects of meat-packing establishments.

CHEMICAL CONTROL.—During this period the scientific development and investigation of insecticides was greatly improved and intensified. The great influence of George D. Shafer's papers "How Insecticides Kill" and the pioneer investigations of William Moore seem to me to have initiated the present era of chemical entomology.

Some of the special contributions of this decade to the vast program of chemical control of insects may be noted. It was first demonstrated that lead arsenate could be used in a practical way in the conquest of the cotton boll weevil; then the next step, the adoption of calcium arsenate for this purpose, was made. Very careful studies of the properties and correct proportions of the arsenates in sprays were made by Tartar, Robinson, Wilson and others. Powdered lead arsenate came into general use instead of the old paste forms. The effectiveness of a weak arsenical bait for the control of the Argentine ant was discovered and has since become the standard measure for fighting many kinds of ants.

Sodium fluoride, although used as an insecticide as early as 1896, really became recognized in the latter part of this decade as a result of its recommendation for cockroaches in 1915, for ants in 1916, and for poultry lice in 1917. These recommendations paved the way for the discovery of the value of the silicofluorides and cryolite as plant sprays. The consumption of these substances, starting at near zero in 1915, now approaches 10,000,000 pounds of sodium fluoride and 5,000,000 pounds of cryolite, annually.

Liquid hydrogen cyanide was first used in fumigation in 1915 and there were great interest and vast improvements in the employment of this gas in citrus and greenhouse insect control. Investigations of the insecticidal value of certain lethal gases used in the war led to the discovery of the value of chloropicrin and initiated a search for new and better fumigants which is still going on.

The effectiveness of paradichlorobenzene for the control of the peach borer was announced in 1915 and it rapidly became the standard method of controlling this pest. Paradichlorobenzene and naphthalene as insecticides for household and stored grain pests were given tests. The value of borax as a poison for house fly maggots in manure was discovered. Early studies of rotenone-bearing insecticides were made. The grasshopper campaigns of 1912–18 established the poison bran bait as a reliable and practicable control for these pests.

This decade witnessed the introduction of calcium arsenate, first tested as an insecticide in 1913 and zinc arsenite in 1911. The first nicotine dusts were used in California in 1917. The forerunner of the numerous *compounds* of nicotine in use today, nicotine oleate, was prepared and recommended. Commercial concentrates of nicotine and nicotine sulphate were widely used.

Lubricating oil and crude oil emulsions were demonstrated to have practical value for the control of certain scale insects and whiteflies. Gas tar, the forerunner of the tar distillate emulsions, was recommended in England. The discovery that the unsaturated hydrocarbons in oils are chiefly responsible for the injury to plants by oil sprays, led to the use of highly refined oils and the present summer-oil emulsions.

Wettable sulphur as a spray was introduced in 1918. Creosote impregnations of telephone and telegraph poles, mine props, and railroad ties, as a protection from wood-eating insects, became widely practiced. The efficiency of flour paste as a spreader was announced. The dem-

onstration by Vermorel and Dantony of the relation between surface tension and the wetting power of sprays led to the vast and important research for improved spreaders and wetting agents.

There were extensive investigations of Bordeaux mixture, very thorough laboratory and field studies of lime-sulphur, including the discovery of its efficiency for the tomato and potato psyllid, its function as a stomach poison, and the development of commercial concentrates. There was an awakening of interest in poisonous spray residues and the poisoning of honey bees. It is interesting to note the search during this time for a satisfactory poison for the Mexican bean beetle in Colorado and New Mexico, well in advance of its spectacular spread over the Eastern States.

INSECTICIDE MACHINERY.—Great progress was made during this decade in the development and improvement of spraying and dusting machinery and equipment. By 1918 machines had been perfected that could develop up to 1,000 pounds pressure, making it possible to use solid stream nozzles and hose lines a mile in length, for the control of gypsy and brown-tail moths on shade and forest trees. There was great interest in dusting as a substitute for spraying for apple and peach insects. Portable machines for generating hydrocyanic acid in citrus fumigation became widely used. The first stationary spray plant was built in California. Vacuum fumigation was perfected about 1914 and its use for the treatment of seeds, nursery stock, and cotton during this decade clearly paved the way for the extensive later development of industrial fumigation of packaged products.

BIOLOGICAL CONTROL.—Rapid strides were made in our knowledge of insect parasites. Improved apparatus and equipment were devised for the study of their behavior and for colonizing and utilizing them in the field. An important conclusion of this decade was that some major pests cannot be mastered by a single parasitic species but require a sequence of different natural enemies, attacking the host in its successive instars and life stages.

Many important studies on entomophagous parasites were published by Townsend (1908), Pantel (1909), Pierce (1910), H. S. Smith (1912), Timberlake (1912, 1916), Tothill (1913), Prell (1915), Imms (1918), Silvestri (1919), Pemberton and Willard (1918), Muesebeck (1918) and others. Basic studies of biological control were made by Howard, Burgess, Fiske, H. S. Smith, and others.

A new departure in the search for biological-control material was made when, in the summer of 1919, laboratories were established in France to study native parasites of the European corn borer; and an entomologist was established in Japan to study the natural enemies of the Japanese beetle in their native environments. There were vast introductions of foreign parasites and predators from Europe and Asia for the control of the gypsy and brown-tail moths, citrus white flies, alfalfa weevil, elm leaf beetle, and the Oriental fruit moth.

The wholesale production of natural enemies by rearing under controlled conditions also characterized this period. In California the rearing of lady beetles in special insectaries, using potato sprouts as a host plant for the mealybug hosts, became a sizable industry. In Florida pure cultures of entomogenous fungi of the genus Aschersonia were reared and used extensively for the control of citrus whiteflies. Other bacterial and fungous enemies of insects which were carefully studied included Entomophthoraceae, Coccobacillus of grasshoppers, and the "wilt" of gypsy moth.

The successful control of cottony-cushion scale in Louisiana by the Australian lady beetle and the attempt to control prickly pear, where it had become a serious weed in Australia, by the use of its natural enemies, are also noteworthy.

LEGAL CONTROL.—The decade beginning in 1910 witnessed profound development in the control and suppression of pests *by legal means.*

A growing demand for a clear statement of the contents of materials sold as insecticides and fungicides and greater honesty in advertising them, resulted in the passage of the National Insecticide Act, approved April 26, 1910, effective January 1, 1911.

In Canada the "Destructive Insect and Pest Act" was passed in May 1910, providing for regulation, restriction, or prohibition of entry of nursery stock into the Dominion and for methods of preventing the spread of pests within the Dominion.

In the United States a fifteen-year fight to secure a national law to prevent the importation of infested and diseased plants resulted in the passage on August 12, 1912, of the "Federal Plant Quarantine Act." This was the first legal authority of the United States government to exclude plant materials infested with insects or disease, although the federal Bureau had begun inspection of imported nursery stock several years earlier, simply by courtesy or tolerance of the importers. The Federal Horticultural Board was organized in 1912 to supervise enforcement of this act. In 1915 terminal inspection of plants in U. S. post offices was begun.

State inspection and insecticide laws followed rapidly. The Florida State Plant Board was created in 1915, and in 1919 the Western Plant Quarantine Board was organized, leading to the creation of similar boards in other sections of the country, an important factor in unifying and coordinating quarantines and inspection requirements. In the same year the sweeping, Federal Plant Quarantine No. 37 became effective.

EXTENSION WORK.—The Agricultural Extension Service developed to a high degree of efficiency during this period. Farm Bureaus became influential; county agricultural agents were appointed in thousands of communities, forming a basis for more effective contacts between entomologists and farmers; and the first well organized, full-time extension entomologists came into existence about 1913. The passage of the Smith-Lever Act in 1914, gave the movement great impetus. Under the Food Production Act, which became effective in 1917, the Bureau of Entomology organized an office of extension work in entomology.

MEDICAL ENTOMOLOGY.—One of the most outstanding characteristics of this third decade we are celebrating was the very greatly increased interest in medical entomology. In his presidential address before the American Association of Economic Entomologists in January 1913, Dr. W. D. Hunter said: "There is no doubt that medical entomology is the branch of our science which is most in the public eye at the present time." And that was before the entry of the U. S. into the war!

The fundamental work on typhus and trench fevers was largely accomplished in this decade, including the discovery of the *Rickettsia* pathogens, proof of their dissemination by body lice, and the method of transmission. Much of the work on Rocky Mountain spotted fever and the establishment of the work by the U. S. Bureau of Entomology and the Public Health Service, in Montana, came at this time. Tularaemia was discovered in one guise and another in 1910, 1913 and 1919. Tick paralysis was reported in the northwest as due to bites of *Dermacentor venustus*. Important studies of human myiases were reported. The discovery of the remarkable egg-laying habit of the human bot fly on the bodies of mosquitoes, in 1913, interests me. The Simulium-pellagra and stable fly-poliomyelitis puzzles were cleared up.

On the veterinary side may be noted the work of Hadwen, Carpenter, and Hewitt on ox warbles, including establishment of the fact that the newly-hatched larvae of both *Hypoderma bovis* and *H. lineata* enter the host near the point where the eggs are laid, thus solving a century-old riddle concerning the life cycle of these parasties. Practical control work was completed on poultry lice, cattle lice, and scab. Some of the great publications in this field of entomology and health, including Nuttall's monumental work on ticks and on human lice, the work of Hunter, Bishopp, Wood and others on ticks, the taxonomic work by Harrison and Kellogg on Mallophaga, the completion of Theobald's great work on mosquitoes, the "Mosquitoes of North and Central America and the West Indies," Banks work on mites, two books on the house fly, and three or four textbooks on medical entomology, appeared during this decade.

Abroad, there was great activity in the study of sleeping sickness and other trypanosomiases in Africa, on verruga in South America, on kala azar, Oriental sore and other tropical leishmaniases, and on Chagas disease in South America. Very important contributions were made to our knowledge of fleas and bubonic plague.

Beginning about 1910, certain State Boards of Health, as in California, appointed entomologists as consultants in control work against mosquitoes, the house fly, human lice, bedbugs and rodents. Recognition of the importance of

entomology to human health, as evidenced by the appointment of several American entomologists to service in the Sanitary Corps during the World War has already been noted.

Much of the present day interest in the control of human parasites and disease carriers dates from the intensification of these problems in military camps during the War. Perhaps the first college course to be offered in medical entomology was by W. B. Herms in 1910–11 at the University of California.

INSECTS AND PLANT DISEASES.—During this decade entomologists became keenly interested in the insect transmission of *plant* diseases, previously a matter of concern chiefly to the plant pathologists. There was much debate concerning the connection of the honey bee with fire blight, and careful studies on the dissemination of this disease by sap-sucking insects. Aphids were incriminated in the spread of spinach blight, and tobacco mosaic. From 1916 to 1918, the striped cucumber beetle was shown to be the disseminator of cucurbit mosaics and cucurbit wilt, and to harbor the bacteria of the latter disease over winter. Chestnut blight dissemination by wood borers was exposed, and a number of beetles found which check the disease by devouring spores in the fruiting pustules.

With reference to certain diseases, previously puzzling, insects were found to be the pathogens themselves rather than the carriers of other pathogens. The relation of the beet leafhopper to "curly-top" of beets and the tarnished plant bug to peach "stop back" were established. Proof that the potato leafhopper causes potato tipburn, suspected as early as 1905, was first clearly furnished at this time.

The necessity for the control of minor pests of tobacco, as well as the major ones, because of the transmission by the former of tobacco mosaic was a thought-producing declaration.

RESISTANCE.—Melander's report on the resistance of San Jose scale to lime-sulfur was new. The idea of plant resistance to insect attack received additional impetus from reports of wheat resistant to Hessian fly, and grain sorghums and corn resistant to chinch bug.

PURE SCIENCE AND ITS APPLICATIONS.—This decade witnessed a better appreciation of the importance of "pure science" and its many applications to economic entomology than any previous period. There was increased interest in the study of the behavior of insects and much activity on the reactions of insects to their physical environment. The basic work of Bachmetjew, Pierce, Hunter, Headlee, Krogh, and others, on the reaction of insects to temperature and humidity may be said to have initiated a series of learned investigations on the relation of these factors to development and the determination of the minimum, optimum, and maximum humidity and temperature ranges for certain insects. Practical applications followed in the work of Dean and others on the superheating of mills and warehouses; hot air machines for treating cotton seed to destroy the pink bollworm; heat for delousing camps and barracks; White's report on the destruction of bee diseases by heat; Back and Pemberton's discovery that cold storage kills the Mediterranean fruit fly; and the announcement that low temperature can be used to control the cigarette beetle and the apple maggot.

The attractivity of ultraviolet rays for certain insects was announced and there was new interest in the reactions of Lepidoptera, *Phyllophaga*, and other insects to light rays of various quality and intensity. The use of Roentgen rays or x-rays was advocated for destroying insects in tobacco products in 1916, in stored foods in 1917, and in packages of cereals in 1919. Insect-proof cartons for cereals and dried fruits were also described. Hutchinson's maggot trap for the house fly, the use of light traps for the cigarette beetle, and the employment of female gypsy moths to trap males, as an aid to scouting for distribution, may be noted. There was much improvement in tree banding materials and methods against the gypsy moth.

Loeb's extensive studies on tropisms served to stimulate interest in the tropic life of insects. Basic studies of the food preferences of insects revealed that even the same insect in different instars may have totally different limitations of food. Thus the newly hatched gypsy moth larvae do not feed on conifers. Intensive studies of behavior revealed significant differences in closely related species. For example, our native Calosomas are voracious predators, but few adults and none

of the larvae climb trees; whereas the European *Calosoma sycophanta* climbs readily all but very smooth-barked trees, and so the latter species, unlike the former, is an important enemy of such arboreal caterpillars as the gypsy moth. Verschaffelt's (1910) incisive analysis of the factors determining food preferences of certain insects such as that of Pieris larvae for the mustard oils in Cruciferae and the Priophorus sawflies for amygdalin in certain Rosaceae; and Howlett's (1912) studies of the response of certain fruit flies to eugenol derivatives are illustrative of the type of searching research that put entomology upon a new plane of scientific accomplishment in this decade.

The earliest studies of the host selection principle were made by Marchal (1908), Pictet (1911), Woods (1915), and Hopkins (1916). The effect of hybridization upon food preferences was studied. In 1917–18, Hopkins and his co-workers developed the bioclimatic law, attempting to reveal a significant relation between altitude, latitude and longitude and the seasonal development of insects and other organisms.

The modern study of insect physiology was perhaps initiated about this time. Phillips and Demuth's research on the behavior of bees is noteworthy. There was a much better appreciation of the importance of the ecological approach to entomological problems due to the work of Adams, Shelford, Allee, Chapman, and others. The use of an insect, Drosophila, by Morgan, Bridges, Sturtevant, and others, in their epoch-making work in genetics, is truly an entomological development of great significance during this decade.

FEDERAL ORGANIZATIONS.—There was, during this period, a steady increase in the number of entomologists employed by the U. S. Department of Agriculture, as well as by state universities and agricultural experiment stations and the establishment of many field laboratories of the Bureau of Entomology. The expenditures of the federal bureau steadily increased from $486,000, in 1910, to $1,185,000, in 1919.

During this decade the Canadian entomological service developed "from a very small unit of the Experimental Farms Branch to an important separate Branch of the Department of Agriculture," established in 1914. From 1912 to 1916 field laboratories were established in eight or more of the Canadian provinces, with well trained entomologists in charge.

IMPROVEMENT IN COOPERATION.—A matter that gives me much pleasure to record was the passing and burial of the old idea of secrecy and jealousy in guarding trade or professional secrets by various entomological research men. The decade preceding 1920 witnessed the development of a fine spirit of cooperation among entomologists, and the substitution of a spirit of progress by sharing, rather than by trying to "beat the other fellow to it." The former practice of administrative heads taking credit for research done by their subordinates seems also largely to have died out about this time.

The First International Congress of Entomology was held at Brussels in August, 1910. The *London Times* in reporting upon this meeting said: "Entomology is at last recognized officially as an important science. The study of insects, so long looked upon with disdain as a pastime for children and old men, has at last vindicated its claim as a valuable branch of human mental activity. From being a purely intellectual exercise, entomology has developed a most important practical aspect that will, in the near future, have a profound and far-reaching effect upon the lives and fortunes of millions. The discovery of the astonishing phenomenon that certain insects transmit such diseases as yellow fever, malaria, and sleeping sickness has a direct and vital influence upon tropical medicine. . . . Entomology has won the serious attention of practical men who, acting together with the purely academcial devotees of pure science, have demonstrated their attachment to and appreciation of their study by organizing an International Congress that received the hearty support of institutes, departments, and governments."

The Imperial Bureau of Entomology was organized in 1913 and that indispensable abstracting journal, the *Review of Applied Entomology*, was started in the same year. The *Journal of Agricultural Research* also begun in 1913, has published many entomological articles.

THE PASSING OF THE ERA OF SIMPLICITY.—The beginning of this decade seems to me to have witnessed what might be termed the demise of the Era of Simplicity in entomology. I remember, as a student from 1907 to 1912, that we considered a great many problems solved. Lime-sulphur was the remedy for scale insects; paste lead arsenate for defoliating pests; kerosene emulsion or nicotine sulphate for other sap-sucking forms. For insects not otherwise controlled, fall plowing was a panacea. The codling moth problem was considered settled. Each species was thought to have a definite number of generations, to winter in one definite stage, to behave in a rather uniform manner—to constitute, in short, one problem the country over. The realization which has become acute in very recent years, that wide generalizations about the control of insect pests cannot be depended upon; but that each insect, in each area, and even when feeding upon each different crop, may be an independent problem, did not bother us then. I fear there was a comfortable feeling that if we knew enough entomology, well enough, that *was* enough.

At the beginning of this period any outstanding young man with a bachelor's degree from a good school could get a job almost as soon as he graduated. The colleges offered few courses and had very few graduate students in entomology. But before the end of the decade, emphasis began to be placed upon a much more extended, more fundamental and broader training; and the necessity of a good knowledge of the whole field of biology, ecology, plant physiology, chemistry, physics and mathematics was realized.

Graduate study was at first emphasized largely because of the inability of many recent graduates to secure employment in their chosen field. Because of this better training and superior ability, the younger men began in this decade to go back and attack many of the large problems, which were previously supposed to have been solved. There was a great improvement in methods, technique, and the profundity with which research problems were attacked, including more scientific planning of experiments, basic studies of cause and effect instead of trial and error, and the beginning of the application of mathematics to the analysis of data.

As evidence of the intensified interest in teaching, we note that at the Minneapolis meeting in 1910 the symposium of these societies was on the teaching of entomology and was participated in by Comstock of Cornell, Fernald of Massachusetts, Osborn of Ohio State, and Bruner of Nebraska.

PUBLICATIONS.—One of the outstanding features of this decade was the production of an astonishing number and variety of entomological books. I doubt if any other period of equal length can boast such a great increase in this type of comprehensive, summarizing literature dealing with varied aspects of our science.

At the outset of this decade, we had

**Kellogg,** "American Insects"
**Comstock,** "Manual"
**Howard,** "Insect Book"
**Folsom,** "Entomology"
**Comstock,** "Insect Life"
**Comstock** and **Kellogg,** "Elements of Insect Anatomy"
**Chittenden,** "Insects Injurious to Vegetables"
**Packard,** "Textbook of Entomology" and "Entomology for Beginners"
**Hunter,** "Elementary Studies in Insect Life"
**Felt,** "Monographs on Insects Affecting Park and Woodland Trees"
**Aldrich,** "Catalogue of N. A. Diptera"
**Ashmead,** "Classification of the Superfamilies of Hymenoptera"
**Williston,** "Manual of the Diptera"
**Scudder,** "Butterfiies of Eastern U. S. and Canada"

During the 10-year period under discussion there appeared the following textbooks and outstanding monographic works:

**Aldrich,** "Sarcophaga and Allies"
**Austen,** "Handbook of Tsetse Flies"
**Banks,** "Catalogue of Nearctic Heteroptera"
**Barnes** and **McDunnough,** "Check List of Lepidoptera of Boreal America"
**Blatchley,** "Coleoptera of Indiana" and "Rhynchophora of Northeastern America"
**Boyce,** "Mosquito or Man?"
**Britton,** "Guide to the Insects of Connecticut"
**Chandler,** "Animal Parasites and Human Disease"
**Comstock,** "The Wings of Insects" and "The Spider Book"
**Crosby** and **Leonard,** "Vegetable Garden Insects"
**Ealand,** "Insects and Man"
**Essig,** "Injurious and Beneficial Insects of California"
**Felt,** "Key to American Insect Galls"
**Graham-Smith,** "Flies in Relation to Disease: Non-Bloodsucking Flies"
**Hindle,** "Flies in Relation to Disease: Bloodsucking Flies"
**Herrick,** "Insects Injurious to the Household" and "Insects of Economic Importance"
**Hewitt,** "The House Fly"

**Holland,** "The Moth Book" and "The Butterfly Book"
**Howard,** "The House Fly"
**Howard, Dyar** and **Knab,** "Mosquitoes of North and Central America and the West Indies"
**Korscheldt,** and his students, a monumental work on *Dytiscus marginalis*
**Lochhead,** "Synopsis of Economic Entomology"
**Lutz,** "Fieldbook of Insects"
**Maxwell-Lefroy,** "Indian Insect Life"
**Nelson,** "Embryology of the Honey Bee"
**O'Kane,** "Injurious Insects"
**Patton** and **Cragg,** "Text Book of Medical Entomology"
**Pierce,** "Manual of Dangerous Insects Likely to be Introduced to the United States through Importation"
**Rau,** "Wasp Studies Afield"
**Riley** and **Johannson,** "Handbook of Medical Entomology"
**Sanderson,** "Insect Pests of Farm, Garden, and Orchard"
**Sanderson** and **Peairs,** "School Entomology"
**Slingerland** and **Crosby,** "Manual of Fruit Insects"
**Thayer,** "Concealing Coloration in the Animal Kingdom"
**Tillyard,** "Biology of the Dragonflies"
**Van Duzee,** "Catalogue of the Hemiptera of America North of Mexico"
**Washburn,** "Injurious Insects and Useful Birds"
**Wheeler,** "Ants, Their Structure, Development, and Behavior."

The *Review of Applied Entomology*, the *Index of American Economic Entomology*, and Dyar's *Insecutor Inscitiae Menstruus* were begun in this decade. Both the JOURNAL OF ECONOMIC ENTOMOLOGY and the *Annals of the Entomological Society of America*, although begun in 1908, experienced their sound establishment during this decade, and, for the first time in American history, there was provided a somewhat adequate outlet for entomological publications.

THE ROLL OF HONOR.—It is, of course, men who make history, so a calling of the roll of honor for this decade seems imperative, though very difficult. Among the hundreds of productive workers, publishing actively during this period, I shall try to mention enough to show the richness and variety of the work being carried on although I am keenly aware that, in doing so, I shall inadvertently omit as many more that should be mentioned.

**Aldrich** on Diptera
**Back** on insects infesting food products
**Ball** on leafhoppers
**Baker** on Aphididae
**Banks** on Acarina and Neuroptera
**Barnes** and **McDunnough** on Lepidoptera
**Bishopp** on human and animal parasites
**Blatchley** on Coleoptera
**Britton** on entomology of Connecticut
**Casey** on Coleoptera
**Caudell** on Orthoptera
**Chittenden** on insects affecting vegetables
**Cockerell** on bees and fossil insects
**Comstock** on wings of insects and teaching
**Cooley** on ticks
**Crampton** on Morphology
**Cushman** on Hymenoptera
**Davis** on cereal and forage insects
**Dean** on grasshoppers, mill insects, teaching
**Dyar** on Lepidoptera
**Ewing** on mites
**Fall** on Coleoptera
**Felt** on gall insects and tree and shrub insects
**Fernald** on Lepidoptera and teaching
**Forbes** on economic entomology
**Gahan** on Hymenoptera
**Gillette** on Aphididae
**Glenn** on nursery inspection
**Gossard** on Hessian fly, Cicada
**Harned** on insects of Mississippi
**Hebard** on Orthoptera
**Headlee** on field crop insects and mosquitoes
**Herrick** on economic entomology
**Hewitt** on Canadian entomology
**Hinds** on insecticides
**Hine** on Diptera
**Hopkins** on forest insects and ecological relations
**Howard** on insects affecting health, and biological control
**Hunter** on cotton insects
**Johannsen** on Mycetophilidae
**C. W. Johnson** on Diptera
**Kellogg** on Mallophaga
**Knab** on Diptera
**Leng** on Coleoptera
**MacGillivray** on morphology and sawflies
**Marlatt** on insecticides, legal control
**A. C. Morgan** on tobacco insects and insecticides
**Morgan, Bridges,** and **Sturtevant** on genetics
**Morse** on Orthoptera
**Nelson** on the honey bee
**Newell** on entomology of Floridia
**Osborn** on Homoptera and teaching
**Parrott** on fruit insects
**Patch** on Aphididae
**Pettitt** on Michigan insects
**Phillips** on apiculture
**Pierce** on Strepsiptera and cotton insects
**Quaintance** on fruit insects and insecticides
**Quayle** on citrus insects and scale insects
**Rehn** on Orthoptera
**Rohwer** on sawflies
**Sanderson** on economic entomology
**Scott** on insecticides
**Snyder** on termites
**Swaine** on bark beetles
**Tillyard** on dragonflies, phylogeny, fossils and wing venation.
**Townsend** on Diptera
**Watson** on Thysanoptera and Aleyrodidae
**Webster** on cereal and forage insects
**Wheeler** on ants
**Williamson** on Odonata
**Woodworth** on fumigation

Some of the greatest spirits ever known in American entomology died during this decade:

ALBERT JOHN COOK (1842–1916)
DAVID W. COQUILLETT (1856–1911)
OTTO HEIDEMANN (1842–1916)
W. G. JOHNSON (1866–1916)
FREDERICK KNAB (1865–1918)
HENRY C. MCCOOK (1837–1911)
MARY ESTHER MURTFELDT (1848–1913)
THEODORE PERGANDE (1840–1916)
SAMUEL H. SCUDDER (1837–1911)
JOHN B. SMITH (1858–1912)
CYRUS THOMAS (1825–1910)
P. R. UHLER (1835–1913)
FRANCIS M. WEBSTER (1849–1916)
S. W. WILLISTON (1852–1918)

SUMMARY.—The emergencies due to the World War revealed to the public how important insects really are and established entomology as a great science, vital to human welfare in many ways. The invasion of a number of very serious foreign pests, probably just shortly before the thorough inspection of foreign nursery stock became legal, first made the great mass of the American people insect-conscious. In this decade, for the first time in American history, the steady flow of dangerous foreign pests into North America in the streams of infested plant products was checked by the passage of effective laws and the creation of organizations to prevent the wholesale distribution of destructive insects and plant diseases by commerce. Great discoveries were made in insecticides and their application. "Fighting insects with insects" became recognized as an effective and practicable principle. Most important discoveries were made in the field of medical entomology. The first effective work of entomologists with plant diseases occurred. There was a pronounced swing toward very fundamental research in the solving of practical problems. The training of young entomologists became much intensified and broadened. There was an unusually long and distinguished list of entomological publications. The beginning of the International Congresses, the establishment of the Federal Horticultural Board, the Agricultural Extension Service, Plant Boards, and many field laboratories, the availability of such avenues of publication as the *Annals*, the JOURNAL OF ECONOMIC ENTOMOLOGY, the *Review of Applied Entomology*, and the excellent series of federal and state bulletins and circulars, the handling of enormous appropriations for the suppression of destructive pests, and the consciousness of ability to serve the public much more intricately and effectively—as a result of all these developments, it seems to me we can say that in the decade from 1909 to 1919 entomology *grew up*, from a simple though serious childhood to a vigorous, useful, recognized, and respected manhood.

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# Fifty Years of Entomological Progress, Part IV, 1919 to 1929[1]

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INTRODUCTION.—Among the many outstanding circumstances that greatly influenced trends in agriculture and entomology the most important during this decade was the phenomenal development of crop production forced by our entrance into the World War due to the necessity of feeding our allies as well as ourselves. Every resource of the farm was taxed to capacity production and the entomologists took their places of responsibility among those who helped to win the war at home as well as abroad. Thus agriculture reached the height of productiveness shortly before the close of the war in 1918 and the acceleration and momentum carried its prosperity beyond the termination of this period in spite of the many circumstances that might have checked it at any time. Only during the year 1920 was there a temporary let-down of the post-war boom that swept on until the depression overtook it in 1929 and struck it down in 1932.

There are many other factors cited as also contributing to the quality of entomological accomplishments during this short span, some of which are discussed later, but lack of space and time require that my paper be limited to those wholly concerned with entomology.

The importance of the role of chemistry

[1] In the preparation of this paper I am greatly indebted to my associates Prof. W. B. Herms, Prof. S. B. Freeborn, Dr. H. H. P. Severin, Prof. W. M. Hoskins, Prof. R. Craig, Prof. J. E. Eckert, Dr. G. F. MacLeod, Dr. J. H. Freitag, Dr. E. G. Linsley, Dr. A. E. Michelbacher, and T. H. G. Aitken all of whom rendered assistance.

in all activities connected with warfare and the return of many trained and practical chemists to public and professional life were responsible for profound changes in the immediate and future development of new insecticides which resulted in the establishment of toxicological research and teaching in entomology throughout the country. The further development of farm and insecticide equipment and machinery; the use of the airplane in scouting, in the application of insecticides, and in the transportation of insect pests and beneficial native insects for biological control; the widespread use of the radio as a means of disseminating information, especially throughout the rural districts; the conception of the idea of the possibilities of exterminating newly established pests and its actual application; the establishment of the insect pest surveys in the United States and Canada and the regular issuance of the insect pest survey bulletins; the remarkable advances made in the fundamental studies of insect phylogeny, anatomy, physiology, and ecology; and many other factors to be mentioned later on have all contributed to what might be termed the golden age in the life of the very young science and profession of entomology.

It is well to point out the fact that many of the developments in entomology which are either referred to or discussed hereafter in this paper owe their origin or discovery to workers in many parts of the world. The prickly pear campaign in Australia and other endeavors to subjugate weeds by insects and the conception of the phase theory in relation to locust migrations are lessons worth remembering as happening at this time.

While it seems hardly possible to discuss accomplishments without some considerable attention to those who were responsible for the actual work, it is a fact that aside from mere mention of names in the body of this paper and a few citations in the terminal bibliography, the limits of this address prohibit any further discussion of the men who made entomology during this period. Permit me to refer to a single individual, Dr. L. O. Howard who, after fifty years' service in the Bureau of Entomology and thirty-three years as chief, not only of the Bureau, but of all American entomology, retired from active service on October 17, 1927. As a group of men we owe more to his influence in establishing our profession than to any other single agent or combination of factors during the half century we are memorializing today!

In 1925 Dr. Howard (1926)* laid before us "the needs of the world as to entomology" and pointed out the necessity for more and extensive investigations into the fundamentals of entomology, a better understanding of agricultural practices, life history studies of the larvae of insects, insect physiology, insect ecology, and the chemistry of insecticides. How well his words have been heeded I shall attempt to show forthwith.

SYSTEMATIC ENTOMOLOGY.—Everyone who has anything to do with nomenclature and the classification of insects is aware of the growing complications in the teaching of systematic entomology, in the determination of species, and in the proper handling of collections. The training of students in entomology made notable changes during the decade. Nearly all of the older teachers who laid the foundations upon which we are still building were still guiding the destinies of entomology: H. T. Fernald, Comstock, Osborn, Forbes, Bruner, Wheeler, Baker, MacGillivray, Woodworth, Garman, Gossard, Lochhead, Gillette, Cockerell, Kellogg, Doane, Pettit, Folsom, Van Dyke, Ball, Patch, Washburn, Needham, Johannsen, and others were still our leaders and counsellors. Not only were most professional entomologists required to obtain a Ph.D. degree, but this degree was made much more difficult to acquire and the whole curriculum was greatly expanded.

The scope of systematic and taxonomic entomology is unlimited and will no doubt continue to be so indefinitely. Brues (1929) has said "taxonomy is the oldest branch of natural history," yet it is still an infant though it may boast a half million named species. While it is impossible to refer to all of the most important works I have chosen those which I thought might be more representative. These are summarized as follows:

McGregor (1920) and McGregor & Newcomer (1928) on mites and especially the taxonomy and biology of the European and other red spiders; Banks & Snyder (1920) on the systematics and dis-

* Dates in parentheses may refer to date of publication or to literature cited.

tribution of termites, and Snyder (1924) on the adaptation to their social life; Needham & Claasen (1925), a monograph of the North American Plecoptera; R. C. Smith (1922), the biology of the Chrysopidae; the very extensive papers on the Thysanoptera by Hood, Morgan, Moulton, and Watson, too numerous to list.

Ferris' (1919–1935) remarkable contributions towards a monograph of the sucking lice; Davis (1919a, 1919b, 1928), the descriptions of new cicadas; Snodgrass (1921a) on the seventeen-year locust; Ball (1924), McAtee (1926), and Lawson (1920) on the Cicadellidae; MacGillivray (1921), Morrison (1923, 1925, 1927), and Ferris (1919, 1920a, 1920b) on the Coccidae; Annand (1928) on the Adelgidae; and A. C. Baker (1920), Gillette & Palmer (1928) on Aphididae.

Harris (1928), on the Nabidae; Hungerford (1919) on the biology of aquatic and semi-aquatic Hemiptera; and Knight (1925) on the Miridae.

In the Coleoptera first rank should be given to the remarkable memoirs of Casey (1910–1924) which were brought to completion, and to the Leng Catalogue of Coleoptera (1920). Among the vast array of other contributions I wish to mention the works of W. J. Brown, Blaisdell, Hatch, Van Dyke, and Notman in the general field; Blake (1927) on the Chrysomelidae; Fisher (1923, 1925, 1926) on the Buprestidae and Cerambycidae; Hyslop (1921) on the genotypes of elaterids; Van Dyke (1928) on the Meloidae; Dawson (1924), Hayes (1925), Sim (1928) on the Scarabaeidae, and Blackman (1922) on the Scolytidae. Pierce (1919) finished his work on the Strepsiptera.

In the Diptera, Aldrich (1924) published many short papers; Alexander (1919–1920) continued his very comprehensive taxonomic studies of the Tipulidae of the world and contributed the crane-flies of New York; Cameron (1926), bionomics of the Tabanidae of Canadian prairies; Cole (1919, 1923, 1927), revisions of the Cyrtidae and Therevidae and a study of the male genitalia; Curran (1925), an immense amount of work on Syrphidae and other flies of the United States and Canada; Root (1922, 1923, 1924a, 1924b, 1929), Freeborn (1924, 1926), and Russell (1925) did remarkably fine work on the larvae and adults of mosquitoes; Dyar (1923, 1928) completed his studies of the Culicidae of the Americas and Dyar & Shannon (1927) revised the Simuliidae; Felt continued his great work on the gall midges. His keys to American insect galls (1918) and to the gall midges (1925) are of great value; Melander and Brues were also among the leaders of America's dipterologists and the former's paper on the Empididae (1927) is worthy of note; Shannon (1926a, 1926b, 1926c) on the Syrphidae and Calliphoridae, and the continued contributions of C. L. Metcalf (1921) on the Syrphidae were unexcelled.

In the Lepidoptera much splendid new and revisional work appeared: Braun on the Microlepidoptera, Dyar & Heinrich (1927), Heinrich (1923, 1926), Busck, Lindsay (1925), and many others.

In the Hymenoptera it appears to me that the most outstanding work was done in the superfamily Ichneumonoidea by Cushman (1921a, 1921b, 1922, 1924), Cushman & Rohwer (1921a, 1921b), Rohwer (1921a), Muesebeck (1921, 1922, 1923, 1927), and Viereck (1925). Other works include those of Fouts on the Platygasterinae; Gahan & Fagan (1923), Phillips & Emery (1920), Huber (1927), and Timberlake (1920) on the Chalcidoidea; Mickel's great contributions (1924), 1928a, 1928b) on the Mutillidae; Rohwer (1921b, 1922) on Nysonnidae and Cladiinae; Rohwer & Fagan (1907–1919), Weld (1921, 1922, 1926), and especially Kinsey (1920a, 1920b, 1922, 1923) on the Cynipidae.

Among special papers dealing with the immature forms of insects are those by Lloyd (1921) on caddis fly larvae; Johannsen (1922) on the larvae and puparia of Stratiomyiidae; Greene (1922, 1924, 1925a, 1925b, 1926) on the larvae and puparia of the Diptera; Krafka (1923) on the head of trichopterous larvae; Craighead (1923) on the larvae of the Cerambycidae; Böving (1927), the larvae of the Galerucinae; Nelson (1924), the morphology of the honey bee larva—a truly fine work; Criddle (1924), on the early stages of grasshoppers; Hamilton (1925) on the morphology, taxonomy, and ecology of the larvae of tiger beetles; and Parker and Böving (1925) on the stages of the blister beetle, *Tricrania sanguinipennis*.

Entomological books have appeared with regularity in this country and while

these are generally used, they are too frequently overlooked in citations and bibliographies as if, as some claim, all books are merely compilations. This claim has no foundation, as I am sure you will agree, even though you may not subscribe to every author's ideas.

In reviewing the third edition of Folsom's Entomology with Special Reference to its Ecological Aspects, Calvert (1923) states: "But who is the entomologist who can write a book on all insects to satisfy all his colleagues?" Books bring together old and new facts and will always be the readily available repositories for multitudinous facts necessary for the student and all professional entomologists and our qualifications to teach and pursue research work depend largely upon our personal libraries. The books which I have selected are arranged according to the alphabetical sequence of the authors and without regard to the subject matter, but certain special works are also to be found elsewhere in this review: Blatchley, the Orthoptera of Northeastern America (1920) and the Heteroptera of Eastern North America (1926); Blatchley & Leng (1916), the Rhynchophora of Northern America; Britton (1911–1927), editor of the Insects of Connecticut, a series of six very valuable and useful volumes; Cockerell (1927), Zoölogy of Colorado; Colcord (1925), Index III to the literature of American Economic Entomology; Felt (1924), Manual of Tree and Shrub Insects; Fernald (1921), Applied Entomology; Ferris (1928), The Principles of Systematic Entomology; Forbes (1923), Lepidoptera of New York; Funkhouser (1927), General Catalogue of the Hemiptera; Herrick (1925), Manual of Injurious Insects; Leng (1920), Catalogue of the Coleoptera; Leonard (1928), A List of the Insects of New York; Lochhead (1919), Class Book of Economic Entomology; Meisel (1924, 1926, 1929), A Bibliography of American Natural History; Metcalf & Flint (1928), Destructive and Useful Insects; Morse (1920), Manual of the Orthoptera of New England; Needham, Frost, and Tothill (1928), Leaf Mining Insects; Parshley (1925), A Bibliography of the North American Hemiptera; Patch (1920), A Little Gateway to Science (beginning a series of charming nature books for children); Wellhouse (1926), How Insects Live; Wheeler, The Social Insects (1923) and Foibles of Insects and Man (1928); Pierce (1921), Sanitary Entomology; Brues (1920), Insects and Human Welfare; J. H. Comstock, the Spider Book (1920), and An Introduction to Entomology (1924); J. A. Comstock (1927), Butterflies of California; and Phillips (1921), Beekeeping.

Paleoentomology owes its chief contributions to the pen of Cockerell (1919, 1921a, 1921b) on the Eocene and Miocene insects mainly from Colorado and Wyoming.

Collections of insects have always been the backbone of systematic entomology and studies in geographical distribution and insect hosts. One of the weak spots in our entomological set-up in this country is the lack of sufficient systematists and technical workers to name, describe, and classify insects adequately and to assemble, properly arrange, and preserve collections which might be made available to workers in all sections of the continent. There are already a sufficient number of scientific organizations attempting this colossal task but nearly every one, whether private, corporate, state, or federal, is in great need of sufficient funds for its immediate demands. Private donations of insects have usually been the main source in building up our collections and I am sorry that I cannot review all the important contributions in this field. Dr. Howard in 1925 has called attention to some of them up to the middle of this particular period. It is pertinent to refer to the acquisition of the Aldrich (1924), Casey, Fernald (1925), and Baker (1927) collections by the U. S. National Museum; the Van Dyke (1924), Blaisdell, Van Duzee (1925), Koebele (1927), Slevin (1927), Fox (1928), and Martin (1928) collections by the California Academy of Sciences; the Treherne (1924) collection by the Canadian National Collection; and the MacGillivray (1925) collection by the University of Illinois.

The adoption of the unit tray system by the U. S. National Museum and the transfer of specimens, begun during this period, has led to a general acceptance of the unit system throughout this continent. Fireproof buildings equipped with tight steel cabinets have greatly added to safety from fire and from museum pests and more modern show cases have en-

abled the public to become more familiar with insects and their importance to the welfare of the human race.

ANATOMY AND PHYSIOLOGY.—In the field of anatomy considerably more has been accomplished than has generally been realized due to the fact that publication is widely scattered and often in non-entomological periodicals. The few citations which I include are but a reminder of the actual amount written and include books or important contributions. To my mind by far the most fundamental and valuable researches in phylogeny and anatomy of this decade are those of Crampton and Snodgrass which appeared throughout this period and which are included in the accompanying bibliography. Other papers are: Du Porte (1920), the muscular system of *Gryllus assimilis* (Fab.); Branch (1922), the internal anatomy of Trichoptera; Ford (1923), a comparative study of the abdominal musculature of orthopteroid insects; Davis (1927), studies of anatomy and histology of *Stenopelmatus fuscus* Hald.; Bromley (1926), the external anatomy of the black horsefly; Cameron (1922), the morphology and histology of the Canadian blackfly; Cole (1927), the terminal abdominal structures of male Diptera; Marshall (1927), Malpighian tubules of the larvae of Heptagenia; Ewing (1928b), the legs of primitive arthropod groups; Kennedy (1922a, 1922b), morphology and phylogeny of certain dragonflies; MacGillivray (1923), external insect anatomy; Stickney (1923), the head capsule of Coleoptera; Walker (1919–1922), the terminal abdominal structures of orthopteroid insects; Walton (1927), the polychaete ancestry of insects; and Yuasa (1920), the anatomy of the head and mouth parts of Orthoptera and Euplexoptera; and the important works of Root, Freeborn, and Russell on mosquitoes, noted elsewhere.

In physiology the development of the olfactometer by McIndoo (1919, 1920, 1921, 1926) was an outstanding achievement which has led the way to a great deal of valuable experimental work. Special works are those of Swingle (1925) and Bertholf (1927) on digestive enzymes; Detwiler (1922), the ventral prothoracic gland of the red-humped caterpillar; Lee (1924, 1925, 1927), Welch (1922), the respiratory system of insects; Muttkowski (1923–24), Bishop (1922, 1923, 1926), Bodine (1925, 1926), and Glaser (1925) on the blood of insects; Bishop, Briggs & Ronzoni (1926) on the body fluid of honeybee larvae; Shafer (1923), growth and molting of Odonata nymphs; Lutz (1924), the perception of ultraviolet by flower-visiting insects; Hilton (1924) on the afferent and efferent pathways in the insect abdomen; Gilmer (1925), a comparative study of the poison apparatus of certain lepidopterous larvae; Sturtevant (1925), the seminal receptacles and accessory glands of Diptera; Schroder (1920), sex determination in *Trialeurodes;* and the great work of Snodgrass (1925), anatomy and physiology of the honeybee.

In embryology Brauer (1925) studied the embryology of *Bruchus quadrimaculatus* Fab.

In ecology there are the works of Hungerford (1919) on the biology and ecology of aquatic and semi-aquatic Hemiptera; of Cook, (1924, 1925) on the distribution of the alfalfa weevil; Luginbill (1928) on the fall armyworm; and of Rau (1922, 1924, 1928) on the habits of bees and other insects.

SERIAL PUBLICATIONS.—Serial publications are the most important outlets for entomological papers and their contents and size give a fair measure of the progress of entomology during any period. It is a well known fact that entomological literature is continuously increasing in bulk as well as in numbers of separate publications. There was a very marked decrease during the World War with a low point during 1915 and 1916, but with a steady increase since that time. The issues of the JOURNAL OF ECONOMIC ENTOMOLOGY and the *Annals of the Entomological Society* of America may serve as examples of the situation during this decade. During this period the smallest issues appeared in 1922 and the largest in 1929 with a sharp increase during the following years.

| YEAR | 1919 | 1922 | 1925 | 1929 | 1931 | 1937 |
|---|---|---|---|---|---|---|
| JOURNAL Pages | 476 | 446 | 872 | 1019 | 1331 | 987 |
| *Annals* Pages | 396 | 376 | 545 | 793 | 942 | 654 |

New serials appearing during the period 1919 to 1929 inclusive are:

1922. The Insect Pest Survey Bulletin, Bureau of Entomology and Plant Quarantine. Canadian Insect Pest Re-

view, Canada Department of Agriculture, Division of Entomology.

1924. Pan-Pacific Entomologist, Pacific Coast Entomological Society.

1926. Biological Abstracts, Union of American Biological Societies.

1926–27. Entomologica Americana: New Series, Brooklyn Entomological Society.

The Insecta part of the *Zoölogical Record* was also issued as a separate volume in 1922.

Dyar's *Insecutor Inscitiae Menstruus* ceased publication with volume 14 in 1926.

MEDICAL ENTOMOLOGY.—In medical entomology the accomplishments are far too subtle and extensive for me to evaluate so I have been compelled to resort to the reviews that have been readily available without consulting the medical literature. I think, however, that this hasty compilation may give a fair idea of the more important phases contributed directly by the entomologists. The arrangement is made by subject. That mosquitoes continue to occupy the attention of entomologists is indicated by the work of Chandler (1920–1921) on the malarial mosquitoes of southern Illinois; the investigations of Herms (1919, 1920, 1921, 1929) and Freeborn (1921, 1926) on the malarial and other mosquitoes in California and of Hearle (1926) in British Columbia; and the anatomical researches of Root (1922, 1923, 1924a, 1924b, 1929) on the larvae and the male genitalia and of Russell (1925) on the larvae of anopheline mosquitoes; and those of Freeborn (1924) on the terminal abdominal structures of male mosquitoes. In 1920 the International Board of the Rockefeller Foundation began cooperative work on yellow fever wherever it was known to exist. Chandler & Rice (1923) and Rice (1923) contributed important observations on dengue fever. Mosquito eradication is treated in a book by Hardenburg (1922). In general control the use of oil-soaked sawdust was recommended by White (1919), but the most important development in the control campaign was the use of the airplane in making surveys (Hearle, 1922) and in applying paris green to kill the larvae (King & Bradley, 1926, Williams, 1927), the value of arsenic as a larvicide having been already established by Barker and Hayne (1921). Borax as a larvicide was advocated by Matheson & Hinman (1929) as the result of their 1928 investigations. Top minnows entered prominently into the recommendations of the U. S. Public Health Service and were also advocated by Hildebrand (1921, 1925) and Park (1922), while Howard (1920b) discussed the possibilities of bats and bat roosts in mosquito control. Howard (1928) also contributed the admirable paper entitled "A Fifty-year Sketch History of Medical Entomology."

The louse problem in relation to the American Expeditionary Forces was ably treated by Moore & Hirschfelder (1919) and by Dunn (1922). Lice were also investigated by Ewing (1924, 1926) and by Florence (1921). Fly problems assumed some interesting phases. Warble flies, according to the Yearbook of the United States Department of Agriculture (1927), were responsible for losses of 50 to 100 million dollars annually. Investigations on these insects were conducted in Canada by Hadwen (1919) and in the United States by Bishopp et al. (1926). Howard (1920a) credits the screw worm, *Cochliomyia*, with causing a loss of four million dollars worth of livestock annually. One of the most sensational achievements was the work on Tularaemia by Francis in 1921 and the investigations relative to the vectors of this very serious disease by Francis (1921), Francis & Mayne (1921), Francis & Lake (1921, 1922), Perry (1928), and Parker (1929). Taxonomic studies have been made by Branch (1923) on *Chironomus;* O'Kane (1926) on black flies in New Hampshire; and Marchand (1920) on the early stages of Tabanidae. Fullaway (1921) contributed a paper on horn fly control in Hawaii. Interesting series of experiments were also made on the uses of repellent sprays for the control of flies attacking dairy cows by Freeborn, Regan & Folger (1925, 1926), Cleveland (1926), and Hall (1928). Rocky Mountain spotted fever tick investigations were continued by Spencer & Parker (1924) and control and eradication by Parker (1919, 1921, 1929), Butler (1921), and Startz (1921). Ewing (1923b, 1925) published papers on the taxonomy of chiggers, a paper on dermanyssid mites (1923), and another (1928a) on injuries caused by the bites and stings of common

arthropods similar to those of Baerg (1924, 1929). Wood (1920) treated the tropical fowl mite recently introduced. The text by Herms on Medical and Veterinary Entomology was revised (1923) and that of Fox (1925) on Insects and Disease of Man was published. These were two important books that appeared in this field.

ECONOMIC ENTOMOLOGY.—In economic entomology there is such a vast array of publications dealing with all phases of the subject as to dishearten anyone from venturing to segregate the grain from the chaff unless one is of the temperament to believe that all is good. I am attempting to list only the most important publications relating to the biology and control of the myriads of insect pests in North America during this decade.

Outstanding features of the period were the extensive control and eradication campaigns conducted in various parts of the country. Control campaigns were waged against termites to the extent of changing building codes in many parts of the country (Snyder, 1927); the European earwig in the Pacific Northwest; the beet leafhopper in the West; the pea aphid in Wisconsin; the Mexican bean beetle and the Japanese beetle in the East; the alfalfa weevil in the Great Basin; the cotton boll weevil in the South; the pale western cutworm and other noctuid moths in the wheat belts of the United States and Canada, and a number of forest insects.

Eradication campaigns were directed against the date palm scale in the Southwest; sweetpotato weevil and the pink bollworm in the South; the European corn borer in the East; and the Mexican fruitfly in the south of Texas.

During this decennium there was considerable interest in the apparent development of resistance or immunity of insects to insecticides ordinarily used for their control which was first noted in red scale by Quayle in 1915 and reported later by Quayle (1922) and by Woglum (1925).

Statistical methods in entomology have been used to a certain degree for many years, but the present extensive and intensive subjection of all entomological data to statistical interpretation was definitely established early in this period. Hyslop (1924) discussed statistical methods in their general application; Hartzell (1924) suggested the use of biometrical methods in the interpretation of codling moth experiments and in 1929 discussed the application of one of Pearson's probability theorems and some special probability equations to entomological data; and many other papers appeared then and since.

THE MOST IMPORTANT INSECT PESTS.—The Mormon cricket, *Anabrus simplex* Haldeman, was quite destructive during 1926–1927, there being outbreaks in Colorado, Montana, and Utah.

The European earwig, *Forficula auricularia* Linn., became a pest of great concern in Seattle, Washington, and in Portland, Oregon, in 1921–1923 (Fulton, 1923) but soon subsided into obscurity. It was first observed in California at Berkeley in 1923.

The periodical cicada, *Magicicada septendecium* (Linn.), appeared as predicted; Brood I in 1927 in relatively small numbers and Brood II in 1928 in much greater numbers and over a larger area.

The pea aphid, *Macrosiphum pisi* (Kalt.), became an important pest of canning peas in Wisconsin in 1923 and was extensively investigated.

The eradication of the date palm scale, *Parlatoria blanchardi* (Targ.), began in Arizona in 1922. An appropriation of $40,000 from the federal government and $25,000 from the State of California in 1928 insured the eventual eradication of this coccid in Arizona and California.

The blackfly, *Aleurocanthus woglumi* Ashby, was thoroughly studied and reported on by Ashby (1920) and by Dietz and Zetek (1920).

The elm leaf beetle, *Galerucella xanthomelaena* (Schrank), reached California in 1924, ninety years after it was first noted at Baltimore in 1834.

The Colorado potato beetle, *Leptinotarsa 10-lineata* (Say), reached British Columbia in 1921 (Treherne, 1921).

The Mexican bean beetle, *Epilachna varivestis* Mulsant, which again devastated beans in New Mexico in 1917 (Merrill, 1917) began its invasion of eastern United States and became a very severe pest throughout the remainder of this decade (Chittenden, 1920; Thomas, 1924).

The Japanese beetle, *Popillia japonica* Newman, discovered in New Jersey in

1916, spread rapidly throughout the neighboring states despite all the efforts of state and federal governments, including Federal Quarantine 35 imposed in 1919, to stop it. In 1923 (Smith, 1923) it spread from an area of 770 square miles to 2500 square miles and in 1924 to 5,122 square miles (Smith & Hadley, 1926).

The plum curculio, *Conotrachelus nenuphar* Herbst, was a serious pest in the South Atlantic States in 1927.

The alfalfa weevil, *Hypera postica* (Gyll.), was established in Oregon in 1919.

The cotton boll weevil, *Anthonomus grandis* Boh., greatly increased its distribution in 1920 to the extent of 41,869 square miles (Coad & Moreland, 1921). The thurberia weevil, *A. grandis thurberiae* Pierce, was first observed attacking commercial cotton in Arizona in 1920.

The pepper weevil, *Anthonomus eugenii* Cano, first appeared in southern California in 1923 and was a pest of considerable importance for several years (Campbell, 1924).

The sweetpotato weevil, *Cylas formicarius* (Fab.), was found in Mississippi in 1917 (Harned, 1929). Investigations began in that year and in 1919 an appropriation of $50,000 and in 1920 an additional amount of $75,000 was given by the federal government for the extermination of the insect in Florida, Louisiana, and Texas (Reinhard, 1923; Graf, 1925; Boyden, 1927). At the end of 1928 the weevil was still present in Alabama, Florida, Louisiana, Mississippi, and Texas; it had been eradicated in Georgia (Harned, 1929).

Flies of the family Trypetidae continued to hold first place in the ranks of dangerous fruit pests likely to be introduced into this country and notable contributions were made by Back & Pemberton in their investigations of the melon fly (1919) and the Mediterranean fruit fly (1919) in Hawaii. The discovery of the walnut husk fly, *Rhagoletis suavis completa* Cresson, in California in 1928 caused considerable concern (Boyce, 1929).

The establishment of the Federal Bulb Quarantine, January 1, 1926, created a great deal of interest and activity in studying the insects involved which resulted in proving the real culprit to be *Merodon equestris* (Fab.) rather than the lesser bulb flies of the genus *Eumerus*.

The frit fly, *Oscinus frit* (Linn.), although first positively identified from Indiana in 1916, was found to be widely distributed in the United States by Aldrich (1920) in 1920.

The European corn borer, *Pyrausta nubilalis* (Hübner), discovered near Boston in 1917, infested 2,200 square miles in 1920, 5,836 square miles in 1922, 16,052 square miles in 1923, 24,773 square miles in 1924, 30,237 square miles in 1925, and 68,380 square miles in 1926. It was first noted in Canada, in Ontario, in 1920. Conferences were held at Albany, New York, and Boston, Massachusetts, by the National Association of Commissioners of Agriculture on August 28 and 29, 1919. The International Corn Borer Committee was formed in 1926 and urged an appropriation of $20,000,000 upon Congress for the year 1927. The 69th Congress appropriated $10,000,000 for a control and eradication campaign in 1927 and the clean-up campaign, involving 2,500,000 acres, got under way on March 21st of that year and continued through 1928. While eradication was not effected, the campaign was declared to be successful by the Department of Agriculture.

The oriental fruit moth, *Grapholitha molesta* (Busck), discovered in the District of Columbia in 1916, was first detected in the peach orchards of Georgia in 1923–1924.

The pea moth, *Laspeyresia nigricana* (Heinrich), proved to be a serious pest in Wisconsin in 1920 and 1921 (Heinrich, 1920).

The potato tuber worm, *Gnorimoschema operculella* (Zeller), became a pest in eastern United States in Maryland in the 1923 (Cory & Sanders, 1926).

The apple and thorn skeletonizer, *Hemerophila pariana* Clerck, proved to be a serious pest in northeastern United States in 1921–1927.

The codling moth, *Carpocapsa pomonella* Linn., became sufficiently destructive to walnuts in southern California to warrant local measures of control in 1919.

The pink bollworm, *Pectinophora gossypiella* Saunders, discovered in Texas in 1917, spread rapidly in spite of an immediate eradication campaign involving an expenditure of $910,000. By 1928 some 300,000 acres were involved in the infested area of Texas.

The sugarcane borer, *Diatraea sac-*

*charalis* Fab., proved to be a serious pest in a number of the Gulf States in 1927.

The pale western cutworm, *Porosagrotis orthogonia* Morr., was one of the most abundant and destructive insects in southwestern Canada in 1926.

FOREST ENTOMOLOGY.—In forest entomology the bioclimatic law as applied to entomological research by Hopkins (1919, 1921) is the most outstanding contribution. The retirement of Hopkins as chief of the Section of Forest Entomology in the Bureau of Entomology in 1923 and the appointment of Craighead as his successor is worthy of note. The first use of the airplane in forest survey work was for the spruce budworm, *Archips fumiferana* (Clem.), in northern Canada by J. M. Swaine in 1920 and the first attempts to control insects from the air were directed against the catalpa sphinx moth, *Ceratomia catalpae* Bdv., in Ohio in 1921 by Neillie and Houser (1922) and later for the spruce budworm in Nova Scotia in 1927 by Swaine (Gibson, 1938). Systematic papers on forest insects include those of Blackman (1922) and Swaine (1925) on barkbeetles; Craighead (1923) on the classification of the larvae of Cerambycidae; Herbert (1919), description of the first species of *Matsucoccus* infesting western yellow pine; and Keen (1928), insect enemies of pines in California.

APICULTURE.—In this brief discussion of apiculture I am indebted to Dr. J. E. Eckert for much of the information and the selected bibliography used. He has suggested that it would be well to call attention to the fact that while beekeeping is a distinct branch of the field of entomology, it is unique in that it has more observers and research workers than any other special field in that subject, and the written reports of all these investigators fill thousands of pages each month of the year. During this period much attention was devoted to a study of the causes and control of bee diseases by White (1919, 1920), Phillips (1922, 1927), Sturtevant (1920–1924) and others; to the reaction of bees to temperature, methods of overwintering, and manipulations of swarm control and honey production by a score or more of investigators. This was also a most prolific period of work in the United States Bee Culture Laboratory and the accomplishments and influence of Phillips, Demuth, and Hambleton have been an inspiration to all other workers in this field. Phillips' text on beekeeping in 1924, Snodgrass' monumental contribution on the anatomy and physiology of the honeybee in 1925, and Nelson's splendid paper on the morphology of the larvae of the honeybee in 1924 have already been noted. The contributions of Bishop on cell metabolism (1922–1923) and on blood (1923) and those of Bishop, Briggs, & Ronzoni (1926) on the body fluids of the larvae are also important. The 186th thousand copy of the 1920 edition of ABC and XYZ of Bee Culture by A. I. and E. R. Root indicates how important this book has been to the beekeepers of this country.

The early works of Bishop (1920) in 1920 on the fertilization of the honeybee and the special investigations of Watson (1927, 1929), who first demonstrated the artificial insemination of queenbees in 1926, opened a field of prolific research participated in by J. W. Nolan and others.

Bee pollination of fruit trees was demonstrated by Hendrickson, 1919, and Tufts & Phillip, 1922, 1923, in California and by Brittain (1928–1932) in Nova Scotia.

The United States standards for honey were prepared by Sechrist and others and issued by the United States Department of Agriculture in 1927.

The bee louse, *Braula coeca* Nitzsch, which is thought possibly to have been introduced into a number of eastern states as early as 1905, was discovered at Grantham, Pennsylvania, by E. H. Hess in 1918 and recorded from Maryland by Argo in 1926.

BIOLOGICAL CONTROL.—In biological control a number of important contributions were made, particularly the introduction and establishment of parasites of the alfalfa weevil (Chamberlin, 1924, 1926), of the European earwig (Atwell & Stearns, 1926), and Japanese beetle (Clausen, King & Teranishi, 1927). Remarkable commercial development was taking place in California under the direction of H. S. Smith (1924) in the propagation of *Cryptolaemus montrouzieri* (Muls.) for the control of the citrophilus mealybug in citrus orchards. In 1928 there were 19 large insectaries in production, representing an investment of about $100,000 and an operating expenditure of over $50,000. In these insec-

taries 42, 131, 133 ladybirds were reared and liberated in the orchards in a single year. *Aphycus lounsburyi* Howard, an effective parasite of the black scale, was introduced in 1919 and established in 1920–1921. The mealybug parasites, *Coccophagus gurneyi* Compere and *Tetracnemis pretiosus* Timberlake, were introduced from Australia and in 1928 and 1929, 11,000,000 were reared and liberated (Brock, 1929). Compere's many papers on the taxonomy of coccid-inhabiting parasites and the excellent paper on the insect parasites of the black scale by Smith and Compere (1928) represent outstanding achievements in investigational work. The great interest in *Trichogramma* and the remarkable methods used for its propagation were begun near the end of this decade by Flanders (1929, 1930) in California and by Hinds & Spencer in 1925, in Louisiana. The first laboratory in Canada devoted to biological control was organized in 1923 at St. Thomas, Ontario, with A. B. Baird in charge. The investigations by Tothill (1922) on the natural control of the fall webworm in Canada are also noteworthy. Foreign though it is, the success in the control of the prickly pear and other pest plants by insects in Australia and New Zealand should be mentioned.

INSECTS IN RELATION TO PLANT DISEASES.—The beet leafhopper, *Eutettix tenellus* (Baker), engaged the attention of a corps of private, state, and government entomologists resulting in a great amount of original research work and extensively published results by Severein, Henderson, Bonquet, Stahl, Carsner, Schwing, Hartung, Carter, Knowlton, and others. Severin developed a remarkable technique in rearing the leafhopper in greenhouses for experimental work and in transmitting and studying the virus. In 1922 and 1923 he recorded, for the first time, the natural breeding places of this important insect and in 1928 he demonstrated also that western tomato blight or tomato yellows was caused by the curly top virus of sugar beets. Carter (1927) proved that the beet leafhopper could recover the virus from extracted plant juice contained in an animal mesentery.

Ball (1919) called attention to the fact that hopperburn of potatoes was caused by *Empoasca fabae* (Harris).

Kunkel (1924, 1926) demonstrated that the aster leafhopper, *Macrosteles divisus* (Uhler), was responsible for the spread of aster yellows virus in New York.

Granovsky in 1928 showed that the common potato leafhopper, *Empoasca fabae* (Harris), is responsible for symptoms known as alfalfa "yellows" or "yellow top."

Doolittle (1920) proved that cucumber mosaic virus was transmitted by the cucumber beetles, *Diabrotica 12-punctata* Olivier and *D. vittata* Fab., as well as by the melon aphid, *Aphis gossypii* Glover.

FOREIGN INSECTS INTRODUCED, 1919–1928.—

1919. European apple sucker, *Psyllia mali* Schmidberger. First reported from Wolfville, Nova Scotia (Brittain, 1921).

1920. The Asiatic beetle, *Anomala orientalis* Waterhouse, collected at New Haven, Conn., by Zappe and Walden, July 16 (Britton, 1924, 1927; Friend, 1929).
The camphor scale, *Pseudaonidia duplex* Ckll., first recognized in New Orleans (Arnold, 1921; Plank, 1925).
The satin moth, *Stilpnotia salicis* (Linn.), discovered near Medford, Mass., and at New Westminister, B. C. (Burgess, 1927).

1921. The oriental beetle, *Aserica castanea* Arrow, first observed near Orange, New Jersey, by Headlee (Hallock, 1929).
Capillate cattle louse, *Solenopotes capillatus* Endl., reported by Bishopp (1921) in the South.

1922. The vegetable weevil, *Listroderes obliquus* Gyll., discovered in Mississippi in 1922 and in California in 1925.

1923. *Muscina pascuorum* Meigen reported from Plummer's Island, Md., by Shannon. *Notaris bimaculatus* Fab. in north central United States (Buchanan, 1923).
The birch leafminer, *Fenusa pumila* Klug, noted in Connecticut and proved to be a serious pest of birches in Connecticut and New York in 1926.
The European weevil, *Hypera rumicis* (Linn.), established in middle

North America (Buchanan, 1923).
The parsley stalk weevil, *Listronotus latiusculus* Boh., discovered on Long Island by Boyce (1927).
Imported willow leaf beetle, *Plagiodera versicolora* Laich., noted near Philadelphia.

1926. *Phyllotreta aerea* Allard, in New York. Proc. Ent. Soc. Wash. 38: 139—1926.

1927. Cabbage weevil, *Ceutorhynchus erysimi* (Fab.), noted at Hartsdale, N. Y. by P. J. Chapman.
The Mexican orange maggot, *Anastrepha ludens* Loew, appeared in the citrus orchards in the lower Rio Grande Valley, Texas (Mackie, 1928).
The olive scale, *Parlatoria oleae* (Colvée), was first noted in North America on privet in Baltimore, Md. (McConnell, 1930).
*Serica similis* Lewis, discovered at Westbury, N. Y. (Hallock, 1929).

1928. *Brachyrhinus cribricollis* (Gyll.) was reported at Montebello, Calif., by R. T. Haymaker.
The dusky-veined walnut aphid, *Callipterus juglandis* Frisch, was reported on English walnut in the Willamette Valley, Ore. (Thompson, 1929).

QUARANTINE.—Matters of importance in national and state quarantine may be summarized as follows:

1919. Federal Quarantine No. 37 regulating the movements of plants and plant products. Effective June 1.

1920. Federal Quarantine No. 43 against the European corn borer. Effective October 1.

1921. California border inspection inaugurated to prevent the introduction of the alfalfa weevil. Twelve stations established by 1924.

1924. Quarantine on grapes from Spain because of Mediterranean fruit fly. Central Plant Quarantine Board formed.

1925. National Plant Quarantine Board organized.

1926. Federal Bulb Quarantine. Effective January 1.

INSECT TOXICOLOGY.—The most conspicuous feature of this decade in economic entomology was the phenomenal development in insect toxicology which certainly still completely dominates the field in insect control investigations. The number of articles and pages in the JOURNAL OF ECONOMIC ENTOMOLOGY devoted to insecticides exceeds those of all other phases of entomology which is testimony to the interest in and importance of this relatively new subject.

Chemical and spray manufacturing companies also entered the picture and there was a remarkable transition of chemists to entomology and entomologists to chemical corporations. So there has grown up a close fraternity between the official economic investigators on the one hand and the representatives of the manufacturers of insecticides on the other which has resulted in great benefits to all parties concerned and, what is even more important, to the advancement of insect toxicology and of insect control and eradication. It was this rapid development in the creation of new and more efficient insecticides that made possible and effective the control and eradication campaigns already referred to. The revolt against arsenical residues on fresh fruits and vegetables resulted in the establishment of a tolerance of 0.035 grains of $As_2O_3$ per pound of fruit in 1927. This latter act had a tremendous effect upon many of the fundamental and more or less permanent practices in insect control and forced a rapid search for nonpoisonous compounds which led the chemists and toxicologists into unexplored fields and completely revolutionized spray materials and practices. The development of high-powered spraying and dusting machinery and utilization of the same for high pressure applications of ordinary sprays and for vapor or fog spraying was just beginning.

The organization of the Crop Protection Institute under the auspices of the National Research Council in 1920 aimed "to bring together manufacturers of insecticides, fungicides and allied commodities with the scientific man in entomology, plant pathology, and agricultural chemistry"—O'Kane.

The spray calendar, first invented by Slingerland in 1894, was still popular in the early part of this decade but expired soon after 1928. A very important contribution to the development of toxicology during this time was the invention and perfection of precision laboratory dusters and sprayers and the method of

quantitative measurements of the toxicity of insecticides by Campbell (1926, 1930). The appearance of the spray gun in 1914 greatly modified spray practices and this tool came into its own in this period (Childs, 1920) and stimulated the invention of better nozzles, rods, and other contrivances for the application of spray materials. Stationary spray plants were constructed first in Washington (Morris, 1924) and the northwest and soon afterwards in California (Moses & Duruz, 1926) and elsewhere. The first liquid dusters appeared in New York in 1925 and in Ohio in 1927.

The airplane was used in connection with surveys of mosquito-breeding places and infested timber in Canada in 1919 and 1920 (Hewitt, 1919, Hearle, 1922, Gibson 1938); in dusting woodland trees in Ohio (Neillie & Houser, 1922), cotton in the South, cranberries in New Jersey, and apples in Oregon in 1925; in the peach orchards of Georgia (Snapp, 1926); in the control of grasshoppers (Granovsky, 1926); and for vegetable pests (Morrill, 1926). The United States Department of Agriculture purchased its first dusting airplane in 1928.

While there was a considerable use of petroleum oil sprays in the early part of this decade (Burrows, 1923; Newcomer, 1924; Melander, 1924, 1926), the discovery of the great value of highly refined types as safe and efficient insecticides by de Ong and Gray in 1926 gave a tremendous impetus to experimental investigations of these materials followed by rapidly increasing manufacture and use of a large variety of emulsions, free oils, and innumerable combinations with spreaders, adhesives, and other insecticides. The physical properties of the oils were standardized as to viscosity and sulphonation. Colloidal clays as emulsifiers for miscible oils were suggested by Yothers and Winston in 1925. Herbert (1924) called attention to stimulation of trees by applications of certain types of oil sprays. The tar-distillate washes developed in England in 1928 added to the many chemicals used as ovicides for bugs and aphids.

Sulfur was being extensively exploited for many purposes. Wettable sulfur was recommended by Farley in New Jersey in 1922; colloidal sulfur in 1924 by Young (1924) and de Ong (1924); new very finely ground dusting sulfurs were on the market in 1928 and the use of commercial lime sulfur, long used as a combination insecticide and fungicide, began to wane in 1928. Dry lime sulfur sent out in 1915 was experimented with in the United States and Australia and reported on in 1920 (Cooper, 1920, Flint, 1920). It was very intensely investigated as an insecticide and reported on by Siegler and Daniels (1922), Abbot, Culver, & Morgan (1926).

Bordeaux was suggested as effective in controlling leafhoppers by Fenton & Hartzell (1922) and de Ong (1927).

Hot water was used for treating narcissus bulbs by Weigel (1928) and for the larvae of Japanese beetle by Fleming & Baker (1928).

Pyrethrum was shown by Duruz to be effective in killing cankerworms in California in 1921 and 1922.

Derris was being tried by Kelsall, Spittall, Gorham, & Walker in Canada in 1926 and in the United States by Roark in 1929 and de Ong in 1930.

Nicotine products in the form of concentrates for sprays were given a great impetus through the invention of nicotine dust by R. E. Smith, who began his investigations in California in 1917 and first reported upon them in 1921. This initial work was followed by experiments throughout the country and results were published by Smith (1921), Smith & Martin (1923), Campbell (1921, 1923), White (1922), MacLeod & Harmon (1923), Headlee & Rudolfs (1923), Cory & Potts (1924), Huckett (1926), and many others. De Ong (1928) called attention to the use of petroleum oil as a carrier for nicotine.

Arsenic, long used as a poison to combat insects, was very generally used in some form for many years. It was recommended as a larvicide for anopheline mosquitoes by Baker & Hayne in 1921 and sodium arsenite dust and spray were used to control the Mormon cricket and lesser migratory grasshopper by Shotwell & Cowan in 1927.

Lead arsenate was still the most important insecticide for the control of codling moth and extensive investigations concerning its composition, actions, and uses were made by Cooley (1920), Fernald & Bourne (1922), Cook & McIndoo (1923), Duruz (1923), Campbell (1926), and

many others. Streeter & Thatcher (1924) were the first to make basic lead arsenate of definite composition. In order to insure more durable coverage with lead arsenate various adhesives came into use in 1912 and were further investigated throughout this decade. The effectiveness of molasses for this purpose was reported by Hartzell (1918), various materials by Moore (1921), and fish oil by Hood (1926) and Dozier (1928).

Trials with casein spreaders were reported by Stearns & Hough in 1922, 1924 and Robinson (1925).

RESIDUES.—One of the greatest shocks ever administered to a group of entomological investigators was the placing of a tolerance of 0.035 grains of $As_2O_3$ per pound of fruit by the federal government in 1927. Through years of patient work the control of the codling moth had been standardized and stabilized through the use of arsenate of lead and while this ruling did not entail the abandonment of this chemical, it did mean that tremendous changes would be necessary to comply with the new restriction. This act, more than any other, induced chemical inquiry in the whole field of insecticides and was, to a large degree, the stimulus that motivated the remarkable researches which sought to replace the stable heavy metals used as poisons for spraying fruits and vegetables with the more unstable organic compounds and which have since explored hitherto unknown depths of chemistry and produced unbelievable results within a single decade. But during these changes it was necessary to provide new ways for applying arsenate of lead so that the spreaders and adhesives would not interfere too greatly with the removal of the arsenical residue from the fruit after harvest.

The use of calcium arsenate dust for the control of the cotton boll weevil proved to be an effective and economical means of controlling this pest according to the findings of Coad & Cassidy (1920), Nickels (1924), Walker (1928), and Grossman (1929).

Electric charges of arsenical particles were recognized by Moore and made known in 1925.

Fluorides were used as poisons as far back as 1889, but it remained for Marcovitch to champion fluosilicates as insecticides in 1924 for the control of the Mexican bean beetle as well as for other agricultural insects and for poultry lice and mites in 1926. He also published extensive studies on toxicity of fluorine compounds in 1928. In 1923 sodium fluosilicate was used in earwig baits in Oregon (Fulton, 1923), in dusting for the cotton boll weevil (Walker, 1928) and in grasshopper baits in 1926 and 1927 and for the control of blister beetles in 1926 by Ingram. Carter & Roark (1928) reported on the composition of fluorides and fluosilicates as insecticides and Marcovitch in 1930 published extensive investigations of cryolite and barium fluosilicate, begun in 1928, as substitutes for arsenical insecticides.

MISCELLANEOUS CONTROL PRACTICES.—Bait pans for emergence studies of the codling moth were apparently first used by Yothers in Washington, in 1923, and reported in 1927 and 1930. The results of studies by Steiner (1929) appeared also at the close of this period. The bait-pan method has played an important part in the life history studies and control of codling moth since that time. The discovery, development and application of attractants and bait traps for detecting and controlling the Japanese beetle, the oriental fruit moth and the tobacco sphinx moth were significant achievements begun in 1925 by L. B. Smith, Richmond, and Peterson and further amplified by Peterson (1927), Frost (1927), Morgan & Lyon (1928), and Richmond & Metzger (1929). The use of a special trap containing geraniol bait for capturing the Japanese beetle and the discovery of amyl salicylate as an attractant for the tobacco sphinx moth are noteworthy accomplishments that may be greatly extended in the future.

Banding material and methods for its application in the control of the gypsy moth were evolved by Collins & Hood (1920) and the invention of chemically treated bands for the destruction of codling moth larvae by Siegler, Brown, Ackerman, & Newcomber (1927), and supplemental investigations by Porter & Sazama (1928), Steiner (1929), and Siegler, Brown, Yothers & Yetter in 1929 were of considerable value in augmenting other measures in reducing the numbers of hibernating larvae on the trees.

The use of creosote-calcium cyanide barriers for chinch bug control was in-

vestigated and suggested by Kelly (1926) in Kansas in 1924 and 1925.

The compatibility of insecticides and fungicides, first presented by Gray in 1914 and revised and visualized in a colored chart in 1918, was investigated and expanded by Robinson in 1927.

Vacuum fumigation with hydrocyanic acid and other gases, utilized by Mackie for the control of the cigarette beetle infesting Philippine tobaccos, was further tested by him for the treatment of dried dates in 1920 and citrus nursery stock in 1922. R. I. Smith (1923) experimented with brown tail moth and European corn borer larvae; and Back & Cotton (1925) reported its general application in insect control. By 1928 vacuum fumigators were in common use and some were large enough to admit a box car. This method of fumigation has greatly facilitated the movement of international and interstate commerce involving certain agricultural products such as baled cotton, cotton seed, nursery stock and the like.

Thallium sulfate, suggested as an insecticide by Popenoe in 1926, has been extensively used in ant poisons in recent years.

Calcium cyanide dust became very important for the control of many insects in this decade. First suggested by Quayle (1922) for orchard fumigation, it was further investigated by Moore (1924) and demonstrated as effective and practical in the destruction of the grape leafhopper by Quayle (1924); for chinch bug by Haseman & Bromley (1924) and Flint & Balduf (1924); for insects in greenhouses by Weigel (1924), for ants by Mantner (1925), for general fumigation of citrus trees by Quayle (1927), and for house fly control by Eddy (1927). In 1925 entomologists in 21 states had made more than 500 tests with this promising and easily applied outdoor fumigant.

Carbon disulfide came into prominence, especially as an emulsion for the control of the subterranean larvae of the Japanese beetle, as the result of the findings of Fleming (1926) and Lipp (1927).

The vaporization of naphthalene especially for the control of red spiders and thrips in greenhouses by Darrow (1928), Parker (1928), Hartzell (1926), and Hartzell & Wilcoxon (1930) as now standardized, is the most effective and practical means of disposing of these very serious greenhouse pests.

Tests with paradichlorobenzene in the control of the peach tree borer were published by Blakeslee in 1919 and gave rise to a considerable amount of research with this new fumigant by Snapp & Alden (1923), Knight (1923), Brinley (1926), Caesar (1927), and many others.

Chloropicrin has also been used to some extent in the fumigation of cereals and cereal products in mills and warehouses (Strand, 1926).

Carbon tetrachloride and ethylene dichloride, applied separately and in combination, came into extensive use following the researches of Back & Cotton (1924) and Cotton & Roark (1927) for the treatment of elevator, mill, warehouse, and household pests in place of carbon disulfide and hydrocyanic acid gas because they are less inflammable and explosive and hence less dangerous.

I should also like to call attention to the organization of the Western Cooperative Spray Project effected by British Columbia, Washington, Idaho, and Montana in 1925.

NECROLOGY.—I feel it appropriate at this time to refer to the fulfillment of the work and the passing of a number of America's most valuable and prominent entomologists. In their memory may we pledge our loyalty to our profession and raise their standards to even higher levels.

1920. **C. Gordon Hewitt,** Entomologist and Consulting Zoologist of Canada, President of the American Association of Economic Entomologists in 1916.

1921. **Charles H. Fernald,** first great teacher of economic entomology in America and founder of the Department of Entomology at Massachusetts State College. President of the American Association of Economic Entomologists, 1896.

1923. **S. W. Foster,** Member of the Bureau of Entomology, who first noted the codling moth as a pest of walnuts in California.
**C. H. Turner,** Professor of Biology and Psychology, Sumner Teacher's College and student of insect behavior and anatomy.

1924. **R. C. Treherne,** Chief, Division Field Crops and Garden Insects, Dominion Department of Agriculture, Canada.
**Albert Koebele,** Entomological Explorer and foremost contributor to biological control.
**A. D. MacGillivray,** Professor of Entomology at the University of Illinois and authority on the Tenthredinidae.
**A. L. Lovett,** State Entomologist and Head of the Department of Entomology, Oregon State College and an early toxicologist.

1925. **W. D. Hunter,** Chief, Section Southern Field Crops, Bureau of Entomology, Member of Federal Horticultural Board, and President of the American Association of Economic Entomologists in 1919.
**Thos. L. Casey,** Colonel, U. S. Army, great American systematic coleopterist, whose collection and library were presented to the U. S. National Museum.
**H. A. Gossard,** Entomologist of the Ohio Experiment Station and President of the American Association of Economic Entomologists in 1925.
**H. W. Wenzel,** Organizer of the Feldman Collecting Social in 1887 and a collector of note. His collection is now at Ohio State University.
**W. P. Wood,** Commercial Entomologist and Parasitologist and former member of the Bureau of Entomology.

1926. **E. T. Cresson,** one of the founders of the American Entomological Society, long its secretary, and America's foremost early hymenopterist.
**Henry Skinner,** prominent member of the American Entomological Society and editor of *Entomological News.*
**Annie Trumbell Slosson,** beloved expo-nent of the study of nature and entomology.

1927. **R. I. Smith,** member of the Federal Horticultural Board.
**C. F. Baker,** teacher, collector of plants and insects, systematic entomologist whose great collection of Philippine and Malayan insects became one of the assets of the U. S. National Museum.
**F. L. Washburn,** Professor of Entomology and Zoology, University of Minnesota and President of the American Association of Economic Entomologists in 1911.
**F. R. Mason,** noted world collector of Coleoptera, whose beautifully prepared collection is now at the Academy of Natural Sciences of Philadelphia.

1928. **Wm. Lochhead,** Professor of Entomology and Zoology, Macdonald College, Quebec, and author.
**E. A. Schwarz,** at his death the oldest living member of the Bureau of Entomology, one of the world's greatest coleopterists, and co-founder of the famous Hubbard-Schwarz collection of Coleoptera now in the Bureau of Entomology.

CONCLUSION.—In conclusion may I make a few personal remarks calling attention to the fact that during this period Dr. L. O. Howard was elected president of the American Association for the Advancement of Science, Dr. C. L. Metcalf, who has just preceded me on this program, became Head of the Department of Entomology at the University of Illinois and was president of the Entomological Society of America in 1934. Professor W. B. Herms was appointed Head of the Division of Entomology and Parasitology, University of California, to succeed Professor C. W. Woodworth in 1920. He was president of the American Association of Economic Entomologists in 1928. Dr. V. L. Kellogg resigned his professorship in entomology at Stanford University to become secretary of the National Research Council in 1920. He was president of the Entomological Society of America in 1915. Arthur Gibson became Dominion Entomologist in 1920, president of the Entomological Society in 1922, and president of the American Association of Economic Entomologists in 1926. Dr. A. D. Hopkins, president of the American Association of Economic Entomologists in 1902, resigned as Chief of the Section of Forest Entomology in the Bureau in 1923. Dr. E. F. Phillips resigned from the Bureau to become Professor of Apiculture at Cornell University in 1924. Dr. C. L. Marlatt, our distinguished first speaker and president of the American Association of Economic Entomology in 1897, after forty years of service in the Bureau of Entomology, succeeded Dr. Howard as Chief in 1927. Dr. E. P. Felt retired in 1928 after thirty years of service as State Entomologist of New York. He was president of the American Association of Economic Entomologists in 1902 and editor of the JOURNAL OF ECONOMIC ENTOMOLOGY from its inception in 1908 until 1936.

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# Fifty Years of Entomological Progress, Part V, 1929 to 1939

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Neither discoveries, progress, achievements, principles, policies, nor fundamental facts can be accurately classified into artificial time periods as to their development. Things important or significant to any decade may have had their origin in a far earlier period. Opportunity and conditions often influence events associated with any period. The relation of discoveries or inventions in fields of endeavor remote from a particular science may not be apparent for many years. For example, certain early inventions which found extended commercial use during the last ten years have played an important part in the work on insects during the closing decade. The radio and airplane are accepted tools of entomologists and have a definite bearing on their accomplishments, how they work, and the kind of work they do.

Economic, political, and climatic conditions have had an important and significant bearing on entomology during the closing decade. New policies as to pest control have been developed. Under the spur of economic needs research has developed noteworthy achievements which have found commercial application. The public has become distinctly insect conscious and the outlook of the entomologist toward his science and its place in the scheme of human endeavor has changed. The importance of research on insects and the application of measures for their control have advanced greatly and gained increasing recognition by government, industry, and the public.

COOPERATION.—To meet these new conditions, entomologists have recognized the need of concerted, integrated, and coordinated action. The idea of cooperation and coordination of effort was not new to them and they readily expanded and improved the machinery for coordination and integration of effort on the basis of previous experience. State, federal, institutional, and industrial entomologists and investigators in related fields have united their efforts, and cooperative planning, execution, and operation on matters relating to insects and their control have developed rapidly during the decade. Periodic conferences to review the results of research, determine recommendations, and outline problems needing further study are now recognized and sponsored by state, federal, and industrial agencies interested in developing ways for controlling many of our important insect pests and utilizing species which are beneficial.

These cooperative endeavors have extended beyond national boundary lines and have in some cases been recognized and approved through formal governmental channels. Our Government and those of Mexico and Cuba have formally sponsored such arrangements. In other cases cooperation, while less formally set up, has been just as real and effective. The entomologists and entomological agencies of Canada have had such an intimate part in some of the cooperative activities that no thought has been given to the fact that individuals from two countries participated.

Economic conditions requiring extensive use of public funds to aid those unemployed and the development of a national program of providing worth-while employment for the needy have given entomologists an opportunity to put into practice and greatly extend their recommendations for insect control. Millions of dollars of local, state, and federal funds provided primarily for relief employment have been expanded on insect control during the decade. Activities carried on under these arrangements have been conducted in every state of the United States and directed against many kinds of insects, including mosquitoes, sand flies, black flies, the codling moth, the browntail moth, scale insects, the beet leafhopper, the sweetpotato weevil, and the thurberia weevil. The projects have varied from those of national significance to those essentially local in nature. Activities of long standing such as that aimed to control and prevent the westward spread of the gypsy moth have used this means to receive added support, with corresponding benefits. Besides aiding in the control of insect pests, all these operations have extended the information on insects and their control and carried an educational benefit the importance of which will be far-reaching.

CLIMATIC FACTORS.—During a considerable part of the decade unusual climatic conditions have prevailed over much of our country. Droughts have been accompanied by extensive outbreaks of certain important, native crop pests. Through surveys conducted cooperatively by state and federal workers, entomologists have been able to give advance information regarding impending outbreaks of grasshoppers, and through previous research to advise how they could best be combated. The widespread nature of these infestations and economic conditions occasioned largely by the extended drought indicated the need for federal aid. The extensive cooperative efforts between the federal government and state and local agencies and individuals to protect crops from grasshoppers during the summer of 1934 and corn from the chinch bug during the same season were previously unparalleled. These activities were followed by other similar cooperative efforts and led to the development and establishment by the federal government of a policy for federal, state, and local cooperation for the control of incipient and emergency outbreaks of insect pests and plant diseases.

The importance of this development will be far-reaching. That the cooperative efforts of the decade directed toward prevention of crop losses from widespread oubreaks of insect pests were worth while may be judged by the saving of crops resulting from these activities. During 1934 local, state, and federal agencies expended approximately $1,000,000 in 8 states to save from chinch bugs corn valued at more than $16,000,000. In 1938 cooperative operations costing $623,370 protected crops on more than 1,375,000 acres in 11 states from the Mormon cricket. The expenditure of $3,936,-

791 in the cooperative effort of 1939 to protect crops of 24 states from grasshoppers resulted in the estimated saving of crops valued at more than $128,000,000.

THE MEDITERRANEAN FRUITFLY.—Economic, political, and climatic factors were not, however, the only ones which influenced entomological activities and presented new problems to the entomologist. The decade was only a few days old when, on April 6, 1929, a pest of international importance, the Mediterranean fruitfly, was discovered to have gained limited establishment in citrus groves in Florida. The eradication of this pest from more than 1,002 properties in 20 counties over an area of between 15,000 and 16,000 square miles stands unparalleled and is an accomplishment that will mark this decade as outstanding in the annals of entomological history. The eradication of this infestation, however, was only one of the important accomplishments associated with this operation. New methods of combating the pest were developed. The so-called bait sprays had their first extensive use. Methods were devised to treat large quantities of fruit so that it could be moved without spreading the infestation. The vapor-heat treatment was developed and given wide commercial application. This method has been extended for use against other pests, and to other plant products and plants, and is a significant accomplishment of the last ten years.

The elimination of this infestation of the Mediterranean fruitfly is not, however, the only instance where an insect pest has been eradicated over a large area during this decade. The effort to eradicate the gypsy moth from approximately 400 square miles in New Jersey was successfully completed. The pink bollworm of cotton was eradicated from a wide area in the Salt River Valley of Arizona and from rather extended areas in northern Florida and southern Georgia. The effort to eradicate the date scale from the date-producing areas of the Southwest was successfully concluded. The accomplishment of this undertaking was largely due to the thorough methods developed and used during the decade. The citrus blackfly was discovered in, and eradicated from, the island of Key West during this period.

THE SCREWWORM.—Large-scale operations for insect control supported by public funds were extended into still other fields. A long-known native pest of animals, the screwworm, appeared for the first time in the southeastern states in 1933. During the two succeeding years it increased in abundance, spread over wide areas, and inflicted heavy losses among all classes of livestock. Stockmen and others in this area knew nothing about the pest or of means for its control. To acquaint them with facts accumulated through research previously conducted, a large-scale educational and demonstration program was carried on by federal and cooperating state agencies. This cooperative effort resulted in a material reduction of losses and the adoption by many livestock owners of practices designed not only to control the pest but also to improve the livestock in the areas affected.

As to the decade draws to a close, entomologists and their associates are engaged in carrying out operations against three introduced insect pests under conditions which have arisen during the last three years. One of these, the white-fringed beetle, is native to South America. It feeds on a wide variety of crops, is known to occur over approximately 60,000 acres in four of the southern states, and has demonstrated its importance as a crop pest in limited sections of southern Alabama and adjacent areas of northern Florida. Another is the pear psylla, first recorded in this country in 1832 and well known to entomologists in the East. It has gained limited establishment in pear orchards in the Spokane Valley of Washington and Idaho. How effective the information developed through years of research on this pest will be as a basis for the suppression and eradication of this incipient infestation remains to be seen. The third and perhaps the most important is the pink bollworm. The infestation of the pink bollworm in the Lower Rio Grande Valley, unless eradicated or effectively controlled, may have far-reaching effect on the agriculture of the South, if not the nation, and on the industries over wide sections of the country. It is the outstanding challenge to the entomologists and pest-control officials of our country.

RESIDUES.—During the decade the concern of the public and health authori-

ties in the possible hazards to health which may be involved in the use of insecticides has increased many fold. Local and state legislation has required that certain insecticides be colored so that they can be distinguished from nonpoisonous household products. In several localities requirements regarding the use of fumigants have been made specific and exacting so as to safeguard the public, the property involved, and even the operator. Regulations have been issued reducing and more accurately prescribing the maximum amounts of residues left by certain insecticides that may remain on food products. These actions, and particularly those relating to what is usually referred to as "spray residue," have had a very definite effect on entomological, chemical, and horticultural research. Many new lines of investigation have been undertaken and emphasis shifted to find ways of meeting the new conditions. Achievements along all these lines have been noteworthy. Insecticide chemists working closely with entomologists have developed new materials and reinvestigated old ones in the effort to find insecticides which do not leave objectionable or hazardous residues. It is the decade of organic insecticidal research. Ten years ago only an occasional patent was issued for a synthetic organic insecticide, and most of these were for mothproofing wool. Today the greater part of the 100 patents issued annually for new insecticides relate to synthetic organic compounds for use in fly sprays or for the control of agricultural pests. The usefulness of certain so-called fish poisons for the control of insects has long been known. As early as 1902 the important active ingredient of certain of these was recognized as rotenone, but it was not until 1932 that its chemical formula was determined. Following this, accurate means of recognizing it and certain related compounds such as deguelin were developed, and this made it possible to determine acceptable methods of standardizing insecticides in which rotenone is the important active ingredient. This important discovery and accompanying developments led to the establishment of a "measuring stick" which gave entomologists a more accurate basis for experimentation with such materials as derris, cubé, and timbo. New control measures have resulted for many important pests and particularly those which attack vegetable crops. The determination that derris and cubé powders could be used to control the pea weevil is one of the high lights of the last five years. An industry which meant a great deal to the prosperity of the Pacific Northwest has been relieved of a production hazard which threatened marked curtailment, if not abandonment. To accomplish this engineers also aided, and developed dusters of a type and size previously unheard of. This achievement is significant also as an example of a concentrated cooperative effort in research between the individual, industry, and state and federal agencies.

THE CODLING MOTH PROBLEM.—Well before the founding of the Association of Economic Entomologists the control of the codling moth had been continuously before entomologists. During the decade now closing much additional information has been gained regarding its habits and responses. These new facts have been used to improve the biological basis for control measures. The effects of various chemicals on the codling moth larva have been vigorously investigated and new insecticides developed. Some of these have been perfected to the stage where growers are now using them—especially nicotine bentonite. Improvements in the ways of removing spray residues from harvested fruit—work in which entomologists have had an active part—have been perhaps the most important accomplishment in the decade in meeting this insect problem. The pressure for a solution of the problem of codling moth control has emphasized the importance of teamwork and coordination of effort. The Codling Moth Conferences and the annual pooling of information are of outstanding credit to entomologists and to the leadership of our Association.

PUBLIC SUPPORT.—During the decade 1929–1939, more money has been expended for work on insects than during any similar period in the history of our country. It has not been possible to obtain accurate figures of expenditures from all sources, so detailed comparisons for various activities or the source of funds cannot be made between the several decades. Reports listing the amount of insecticides and insecticidal machinery sold or manufactured during various

years are convincing evidence that those who endeavor to control insect pests have spent considerably larger amounts for this purpose during the last ten years than previously. In the United States 45,000,000 pounds of calcium arsenate were used in 1936 as compared with less than 5,500,000 in 1926; more than 15,500,000 pounds of pyrethrum in 1935 as compared with approximately 9,800,000 in 1926; more than half a million pounds of derris and a million and three-quarters pounds of cubé in 1936 as compared with practically none in 1926. Available figures on the amount expended by industrial concerns for research to determine new materials and devices for insect control or to extend the use of old ones clearly show that industry is spending more in the entomological field. The amounts expended for all work on insects by state agencies or neighboring countries have not been assembled. The contributions by states to cooperative efforts to control insect pests, however, leave little room to doubt that during the decade they also have spent more on insects.

The amount of federal funds expended for work on insects is perhaps the best single index of the general trend of the use of public monies for this purpose. Conditions peculiar to the decade make it inadvisable to use the full amount of such expenditures for comparative purposes. Operations to control and prevent the spread of insects or to combat incipient or emergency outbreaks depend on many factors, and expenditures for these purposes may not be a reliable criterion for estimating public support for work on insects. It is believed, however, that the amounts provided by the federal government for research on insects will give a fair basis on which to judge the public's interest in and support of entomology. For the fiscal year 1929 the federal appropriations for research activities carried on by what is now the Bureau of Entomology and Plant Quarantine were approximately $300,000 more than the amount appropriated for the fiscal year 1928, when the appropriation reached the peak for the preceding decade. Three years later, 1932, the amount had increased about $750,000 above that provided in 1929. The all-time peak of 1932 was followed by a retrenchment, the amount available for the fiscal year 1935 being the lowest during the past decade. Even during this year the expenditures exceeded the appropriations for the fiscal year 1928 by more than $70,000. Since the fiscal year 1935 there has been a gradual increase in the federal appropriations for research on insects. The amount appropriated for the fiscal year 1939 was $2,309,885, which is $379,885 more than the amount available for the fiscal year 1929, or approximately three-quarters of a million greater than the peak of the preceding ten-year period.

PUBLICITY.—The past decade perhaps to a greater extent than any other period has seen concerted effort on the part of entomologists and others to make available to the public information about insects and the work of entomologists. Two books by the same author which did much in this field were issued at the beginning of the decade. Those referred to are "A History of Applied Entomology" and "The Insect Menace." Although directed primarily to the attention of entomologists, these and numerous other books which appeared during the period have found a wide popular interest. A goodly number of small publications giving short well-written accounts of insects and their habits have met with such demand that reprinting was required. Colored illustrations of some of the common species, especially butterflies and moths, have been popular enough to be sold in some of the large 5- and 10-cent stores.

Newspapers have devoted thousands of columns to articles on insects. Although the greater part of these have related to activities of a few species of economic importance, many short and informing notes have been included. Information about insects have reached thousands through the radio; even the sounds made by them have been broadcast. Motion pictures on insects, their habits, development, and means of control, have advanced with the improvement of the art and have played a useful part in informing the public.

Significant and important as all the increased effort of the decade has been to acquaint the public about insects and entomologists, the Association's committee on popularizing entomology still has abundant reason to continue and extend its activities. In recognizing the value and

need for work of this nature our Association has performed a service and has laid the groundwork for a still greater realization of the importance of entomology.

The growing interest in entomology, the general recognition of its importance and how this has changed during the decade, may be judged in part by the definite increase in the membership of the two important national entomological organizations. The 1928 list of members of the Association of Economic Entomologists contains 935 names. The list for 1938 includes 1,184 names, an increase of 249. Similarly the 1928 list of members of the Entomological Society of America contains 838 names, while the one for 1938 has 949 names, an increase of 111. The membership in these two national societies was increased by 360 during the decade.

In our country and abroad new entomological societies have been formed during the ten-year period. That this increasing interest is not sectional, even in our country, is evident when we recall the names of only five—The Insecticide Society of Washington, The Newell Entomological Society, The Thomas Say Entomological Society, The Texas Entomological Society, and the Oregon Entomological Society, this last being the "baby" of the lot, having been organized November 18, 1939, with 35 persons present at the initial meeting.

Fifty-four periodicals containing technical articles on entomology issued their first number during the decade closing with the current year. This excludes two special series—Mitteilungen of the Deutsche Entomologische Gesellschaft and Memoirs of the Entomological Society of Washington—begun during the period. Of these 54 new entomological periodicals, 29 are published in Europe, 6 each in China and Japan, 2 in India, 1 each in Brazil, South Africa, and the East Indies, and 8 in the United States. Those of the United States include the *Journal of the Kansas Entomological Society*, *Microentomology*, *Vedalia*, and *The Extension Entomologist*.

RESEARCH.—With an increase in numbers of students of entomology such as there has been during the period under discussion, it is natural to expect that there would be an increase in the amount of research carried on. That this has been the case is evident by the number of new entomological publications and the increase in size of some of those begun many decades earlier. *The Annals of the Entomological Society of America* included 4,704 pages for the decade ended in 1928 as compared with 7,518 in the closing decade—an increase of 2,814 pages. Some publications, like the JOURNAL OF ECONOMIC ENTOMOLOGY, have changed their format to get more material on the same number of pages. A comparison of numbers of printed pages would fail to give a correct picture of the increase in the amount of material printed. That such an increase has occurred, however, is clearly evident.

That research during the decade and the years immediately preceding has developed important new information may be judged by the number of new revised editions of many of the standard entomological textbooks. Revised editions of 13 of the better known ones have appeared during the decade. All but 4 of these appeared since 1935, and two were issued only one year earlier. There have been 13 extensive new publications on general entomology and 21 on economic entomology—the latter ranging in size from 288 to 884 pages. Bibliographies, catalogues, and books of an historical nature, of which there have been a fair number, have been omitted from these statistics.

Much of the research has been along new lines, and there has been a marked increase in studies which had received the attention of only a comparatively few investigators in earlier years. There has been a noted increase in the number of articles describing the immature stages of insects. Judging from the references in the *Zoological Record*, this increase started about 1932. References to accounts of insect eggs and larvae in the *Record* for 1937 are, respectively, more than 20 and 4 times as great in number as in the *Record* for 1930. To index readily the literature of work along new lines, librarians have added new subjects to their indices, such as Plants Resistant to Insect Attack and Injection of Plants to Combat Insects.

The increased interest in research has been accompanied by an increasing care in planning the work and analyzing the results. Carefully planned field experi-

ments with adequate replicates, where the host plant or animal can develop under conditions suitable for getting accurate records of yield or growth, have become the rule. A number of publications discussing the outlining standard laboratory methods have been issued. References to definite procedures and practices of field and laboratory technique are almost as frequent in entomological literature as they are in the literature of such sciences as chemistry and experimental biology.

With the rapid progress and increase in amount of research it would not be practicable, if it were at all possible, for a single individual to attempt to chronicle or evaluate that which is noteworthy for the decade. Much of it is far too recent to have yet been subject to that critical analysis that all research must undergo before it is accepted and classified as to merit. To omit reference to all would, however, not be in keeping with the developments of the period. Examples have been selected at random from a few fields with no claim that they represent the outstanding contributions of the general field in which they fall and without attempt to measure their true economic significance. To do the latter would exclude some, as there is abundant proof that satisfactory field results for one or even three or four seasons is not adequate for fully appraising the usefulness of a material or device thought to furnish a new and effective way of controlling a particular pest. Examples of some important research contributions follow.

1. That on ethylene dichloride for the control of peach borers.
2. That of various agencies on tar oil distillates and the so-called DN compounds, with the aim of replacing the delayed dormant sprays applied to fruit trees.
3. That of a goodly number of experimenters on cuprous cyanide and particularly that done on certain insects, such as the tomato pinworm, which attack vegetables.
4. The extensive investigations, both chemical and entomological, with fluorine compounds, especially cryolite, to determine their properties and usefulness for the control of many kinds of insect pests, extending even to baits for Mormon crickets.
5. The importation into California of natural enemies of the citrophilus mealybug which led to the attainment of commercial control in two years.
6. The introduction and colonization of a parasite of the citrus blackfly into Cuba and other countries and the resulting commercial control there in a relatively short time.
7. The establishment of *Aphelinus mali* in the Pacific Northwest, resulting in the control of the woolly apple aphid and removing the seriousness of perennial canker disease as a problem in that section.
8. The colonization in Puerto Rico of several species of coccinellid beetles which preyed on the coconut scale and effected satisfactory control.
9. The demonstration that the so-called "sun-curing method" of insect control would lessen the cost of combating important species of tree-killing beetles.
10. The determination of methods of indicating trees most likely to be attacked by bark beetles and their relation to selective logging, timber salvaging, and controlling incipient outbreaks of these pests.
11. The development of combinations of chemicals and light oils which can be used during the summer to control the mountain pine beetle.
12. The combined effort of entomologists and foresters resulting in the determination of silvicultural practices to prevent damage of white pines by the white pine weevil.
13. The investigations which showed that conservative turpentining practices would increase the yield of gum, help control the turpentine borer, and prolong turpentining operations in a given area.
14. The experimental work of introducing chemicals in the sap stream of trees for the control of insects and the prevention of future injury to the wood.
15. The preparation of an extract from certain glands of the female gypsy moth and its use as an aid in detecting the presence of the insect in lightly infested areas.
16. The discovery of parafoulbrood of bees and its causative organism.
17. The work on pollen substitutes and the chemical composition of bees.
18. The relation of pollen to the economy of the beehive and its manipulation to increase honey production.
19. The importance of sugar concentration of nectars to the flight activity of the honeybee.
20. The studies on the composition and food value of royal jelly.
21. The determination that the American dog tick, *Dermacentor variabilis*, is responsible for the transmission of the eastern type of Rocky Mountain spotted fever.
22. The demonstration that the rather serious disease of cattle known as anaplasmosis can be transmitted by the American dog tick, *Dermacentor variabilis*, and that *andersoni* and *occidentalis* also transmit this disease.
23. The association of relapsing fever of man in the United States with a tick, *Ornithodoros turicata*, the subsequent knowledge of the distribution of the disease in the United States, and the proof that *hermsi* is responsible for the transmission of the disease in California.
24. The record of occurrence in the United States of the malady of man known as chagas disease and the determination that it is transmitted by species of bugs of the genus *Triatoma*.
25. The determination that 31 species of fleas occurring on domestic and wild animals in the Western States are potential vectors of bubonic plague, that many species of wild animals are susceptible to the disease, and that it now oc-

curs in practically all the states in the Rocky Mountains.

26. That the tropical rat flea can transmit endemic typhus and that this disease of man is widespread in this country, particularly in the Southern States.
27. That the most widespread and deadly malady of horses, encephalomyelitis, can be transmitted by *Aedes* mosquitoes and that this disease is transmissible to man.
28. That under the common term "screwworm" there were included two distinct species of flies differing markedly in their habits.
29. That diphenylamine, one of the synthetic organic compounds used in connection with the dye industry, can be used to protect wounds of animals from attack by screwworms.
30. That certain protein compounds are effective lures for several species of fruitflies which are of economic importance.
31. That tartar emetic in a sweetened solution can be effectively used to control certain species of fruitflies and thrips.
32. That combinations of sulfur and paris green when applied as dusts will effectively control a number of sucking insects which feed on cotton, and will greatly increase the yield.
33. That methyl bromide is an effective fumigant for many kinds of insects and that it can be safely applied to many kinds of living plants and to certain fruits and vegetables.
34. The determination of the chemical formula of pyrethrins—the active ingredients of an insecticide known long before entomology was recognized as a science.
35. The development of a device to record the heart action of insects and the determination of the effect that various chemicals have on its responses.
36. The development, in cooperation with the agronomists, of varieties of wheat resistant to the attacks of the hessian fly.
37. The investigations which show that certain varieties of corn are tolerant to the presence of the European corn borer.
38. The determination that certain inconspicuous and heretofore unimportant aphids on sugarcane may transmit sugarcane mosaic.
39. The development of insecticides which can be used to control the European corn borer on sweet corn and on certain flowering plants such as dahlias.
40. The determination that certain species of bark beetles are carriers of the Dutch elm disease and are the most important means of spreading the disease to healthy trees.
41. That corn can be protected from attack of the corn ear worm by the use of certain devices which can be profitably applied to high-value crops.
42. That there are a goodly number of closely related species of the genus *Anastrepha* which differ in habits and have heretofore not been distinguished.
43. That certain varieties of alfalfa are highly resistant to attack by the pea aphid.
44. That large numbers of insects occur in the upper air and that they may be carried long distances by air currents.
45. The development of aliphatic thiocyanates and isobutyl undecylenamide, and the determination of their usefulness as insecticides.
46. The exact studies on the histology of the body wall of insects, its chemical composition, permeability, and general functions, including the mode of muscle attachment.
47. The extensive studies on the histology of blood cells of insects and the determination of the course of the blood in circulation.
48. The studies on the external genital structures of male insects and the determination of the relation of various parts.
49. The comprehensive contributions on the characters which may be used to distinguish the larvae of Coleoptera.
50. The various studies on the histology of the insect stomach, the processes of digestion and absorption, and the formation of the peritrophic membrane.

One of the most interesting developments and one which constitutes an important chapter in economic entomology which began and has reached high development during the decade is that concerned with and related to the use of maggots in surgery. The announcement that blowfly maggots were of distinct value in the treatment of chronic osteomyelitis in man was announced in 1931. Methods of producing sterile maggots were soon developed and maggot therapy rather widely used. Studies of the mechanism by which maggots cleared out necrotic tissue and stimulated healing led to the discovery of a number of compounds in the excretions of the maggots that are highly favorable to the healing of indolent sores. The first to be recognized was allantoin. This was closely followed by urea and report on a third, ammonium carbonate, is now in press. These materials can all be made synthetically and are readily available. The detailed and critical studies on certain insects and their secretions have, however, led the way to the determination of their use in alleviating sufferings of man.

That history will point to the closing decade as a period of many important accomplishments in entomology and an era during which many far-reaching policies and procedures regarding insect control were established seems assured.

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IDAHO'S quarantine order (No. 25) relating to pear thrips in California was repealed on December 5, 1939, in view of the fact that it was considered "no longer necessary for the protection of Idaho's pear industry from said pest."

# Tests with Methyl Bromide as a Fumigant for Larvae of the Artichoke Plume Moth*

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Methyl bromide has been used since 1935 in California for the solution of a number of entomological problems. This success has led to the present tests which have been concerned with the possibility of using this material as a fumigant to free artichoke planting stock from larvae or other stages of the artichoke plume moth, *Platyptilia carduidactyla* (Riley).

Fig. 1.—Propagation of artichoke plants by old rootstock, left, and young offshoot, right.

The low solubility of methyl bromide in water, its non-combustible nature and its successful use in many instances on delicate plant tissues without apparent injury, make it very applicable to a problem of this nature where succulent artichoke off-shoots are to be fumigated.

The first industrial application of methyl bromide in this country was made by the California State Department of Agriculture in 1936 under Mackie for the control of the potato tuber worm in Shafter potatoes. Mackie (1937) and Mackie and Carter (1937) presented the earlier work in California, especially that in relation to the fumigation of fresh fruits and vegetables, plants and stored products. Lindgren (1936, 1937) used a commercial mixture of methyl bromide and carbon dioxide, reporting good results on codling moth larvae in empty walnut sacks. Mackie (1938) covered the history of methyl bromide and its many applications to fumigation problems in California. Fisk and Shepard (1938) have presented laboratory tests in which methyl bromide compared favorably with hydrocyanic acid, chloropicrin, and ethylene oxide. Using methyl bromide as a fumigant for apples Phillips, Monro and Allen (1938), under certain conditions, obtained some internal and external injury that was thought to be of physiological rather than of mechanical origin.

It is the customary practice among artichoke growers in replanting to plant either a part of the main plant with a central stem, or a succulent offshoot, with the result, especially in the latter case, that infestations are spread from one field to others or transported some distance to new artichoke plantings (Fig. 1). The larvae are not readily seen as they are, for the most part, internal borers in the stems or leaf petioles (Fig. 2). Inasmuch as the plume moth is found in California widely distributed on *Cirsium* thistles, the use of "clean" planting stock alone in new artichoke growing areas would not suffice, but would be expected to assist in averting or delaying infestation where thistles have been properly destroyed. The use of "clean" planting stock in the present artichoke areas would be of little value unless practiced on all the fields in an individual area at a definite time. The perennial nature of the plants and the customary practice of replanting only part of a field each year would result in prompt re-infestation of fumigated plants. There is also the fact to be considered

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that in an area where artichokes are grown year after year there is a population of moths about, even if all the artichoke plants are removed, and a certain "artichoke free" period would have to be allowed if re-infestation were to be forestalled.

METHODS.—In the vacuum fumigation tests the material to be treated was first introduced into the fumatorium (capacity 100 cu. ft.), and the air exhausted to the necessary vacuum. The properly measured amount of methyl bromide and air were simultaneously introduced into the chamber by the time the gauge registered 5″ mercury vacuum. Exposure occurred at atmospheric pressure.* Fans were run continuously to prevent stratification. The length of exposure varied with the different tests after which the chamber was again evacuated to 20–29″ vacuum, the valves then being slowly

FIG. 2.—Larvae of the artichoke plume moth boring internally in leaf petioles of the artichoke.

opened to restore atmospheric pressure. Then with the fans still running, the material was removed. In the atmospheric tests a 5″ vacuum was created in order to draw in the methyl bromide and exposure followed at atmospheric pressure.

Each test included both damaged artichokes and infested plants. (Fig. 3). In most of the tests mortality counts of the larvae were made from the artichokes, and

FIG. 3.—Test lot of artichokes and plants used in fumigation experiments.

the plants were set out in the ground to record any plant injury. The usual prefumigation treatment of the plants was to keep them slightly dampened with water without removing them from the boxes, but in a few cases the plants were kept saturated with water or allowed to dry out. The check lots of plants and artichokes received pre- and post-treatment similar to those lots used in the fumigation experiments. Plants were collected the day prior to their treatment. After treatment the artichokes were placed in a cool place and mortality counts made after 48 hours. The plants were placed in the ground within ten hours after treatment and irrigated. Larvae which still showed movement at 48 hours were placed in Stender dishes with pieces of artichoke heads to record their survival or death. The methyl bromide used in these tests was at least 99.5 per cent pure.

* Mean atmospheric pressure (reduced to sea level) for Sacramento during these tests was: Oct. 1937, 29.98; Mar. 1938 30.04; Apr. 1938, 30.03 (U. S. D. A., Weather Bureau).

**Table 1.—Toxicity of $CH_3Br$ as a fumigant to artichoke plume moth larvae 48 hours after treatment and to artichoke plants set out in the ground 10 hours following their exposure.**

| Exp. | Date | Details of Fumigation: Temp. (°F.) | Vacuum (inches) | Dosage (lbs. per M. cu. ft.) | Exposure (minutes) | Material Treated: Number plants | Number artichokes | Per Cent Kill of Larvae in 48 Hours: In plants | In artichokes | Per Cent Kill of Plants Set Out in Ground: In 20 days | In 40 days |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 10–22–37 | 76 | 27 | 2½ | 90 | 8 | 63 | 100 | 98 | — | — |
| 2 | 10–22–37 | 80 | 27 | 1 | 90 | 8 | 63 | 100 | 60 | — | — |
| 3 | 10–22–37 | 80 | Atmospheric | 2 | 120 | 8 | 63 | 100 | 100 | — | — |
| 4 | 10–22–37 | | Check for exp. 1–3 | | | | | 0 | 0 | — | — |
| 5 | 3– 7–38 | 55 | 25 | 1½ | 90 | 25 | 50 | 100 | 96 | 13 | 43 |
| 6 | 3– 7–38 | 55 | 25 | 2 | 90 | 25 | 50 | 87 | 94 | 4 | 42 |
| 7 | 3– 7–38 | 56 | 25 | 2½ | 90 | 25 | 50 | 100 | 97 | 8 | 54 |
| 8 | 3– 7–38 | 55 | Atmospheric | 2 | 180 | 25 | 50 | 100 | 100 | 50 | 96 |
| 9 | 3– 7–38 | | Check for exp. 5–8 | | | | | 0 | 0 | 8 | 17 |
| 10 | 4–19–38 | 71 | 20 | 2½ | 90 | 30 | 50 | — | 99 | (Lot 1) 85* | 83 |
| | | | | | | | | | | (Lot 2) 0† | 23 |
| | | | | | | | | | | (Lot 3) 23‡ | 69 |
| 11 | 4–19–38 | 74 | 20 | 2 | 90 | 30 | 50 | — | 100 | 36 | 79 |
| 12 | 4–19–38 | 74 | 20 | 1½ | 90 | 30 | 50 | — | 100 | 38 | 63 |
| 13 | 4–19–38 | 75 | 20 | 1 | 90 | 30 | 50 | — | 87 | 47 | 53 |
| 14 | 4–20–38 | 63 | 20 | ½ | 90 | 30 | 50 | — | 9 | 0 | 14 |
| 15 | 4–20–38 | 64 | 29 | 2½ | 90 | 30 | 50 | — | 98 | (Lot 1) 92§ | 92 |
| | | | | | | | | | | (Lot 2) 45† | 70 |
| 16 | 4–20–38 | 70 | 20 | 1 | 60 | 30 | 50 | — | 44 | 22 | 33 |
| 17 | 4–20–38 | 76 | Atmospheric | ½ | 960 | 30 | 50 | — | 100 | 32 | 63 |
| 18 | 4–20–38 | | Check for exp. 10–21 twice evacuated to 20″ | | | | | | 3 | 0 | 0 |
| 19 | 4–20–38 | 72 | 20 | 1 | 120 | 30 | 50 | — | 99 | 0 | 14 |
| 20 | 4–20–38 | 76 | 20 | 1 | 150 | 30 | 50 | — | 98 | 0 | 0 |
| 21 | 4–20–38 | | Check for exp. 10–21 not evacuated | | | | | — | 0 | 0 | 0 |

* Plants submerged for 2 hours prior to treatment in water and kept wet up to time of planting.
† Plants given regular treatment—lightly sprinkled with water.
‡ Plants kept dry prior to and after treatment.
§ Plants given regular treatment prior to treatment; given a post treatment of 1 pound $NaHCO_3$ to 5 gallons water for 30 minutes.

TOXICITY TO LARVAE.—The results obtained on the toxicity of methyl bromide to the larvae of the plume moth are presented in Table 1. In the vacuum fumigation tests dosages of 1½ to 2½ pounds per 1,000 cu. ft. with an exposure of 90 minutes showed 94 to 100 per cent kill when examined 48 hours after treatment, with any surviving larvae gradually dying in from 2 to 14 days. This delayed kill of the larvae of insects was recorded also by Mackie and Carter (1937) and would certainly have to be taken into consideration in determining the success of tests of this nature. The affected larvae remain in a moribund state, refuse to eat, and gradually discolor and die. When the dosage was reduced to 1 pound per 1,000 cu. ft. with a 60 to 90 minute exposure, toxicity to the larvae became noticeably less and 68 to 86 per cent of the larvae were alive at the end of 14 days following the fumigation treatment. An increase in the exposure period to from 120 to 150 minutes using the 1 pound dosage, on the other hand, gave 98 to 99 per cent kill at 48 hours and the surviving larvae died in from 2 to 12 days.

FIG. 4.—Mature larvae of the artichoke plume moth, enlarged approximately ×3.

Several exposures were made at atmospheric pressure with different dosages and periods of exposure, and in all cases a perfect kill of larvae was obtained.

TOXICITY TO PLANTS.—The plants showed no immediate effects or apparent injury from the methyl bromide treatments. When planted, however, there was a very noticeable slowing up in the growth as compared with the checks, with wilting in 10 to 20 days or death in 20 to 40 days. This plant injury therefore became an important factor in using methyl bromide for the fumigation of artichoke plants. Certain checks were twice evacuated to 20″ so the injury was apparently not of a

mechanical nature. In setting out the plants a check row was planted in each case on each side of a fumigated row so that the injury could not be attributed to differences in soil or culture. Toxicity of the methyl bromide to the plants as recorded by plant death is given in table 1. It was indicated that plants kept saturated with water or allowed to dry out before and after treatment had a greater mortality than those which were kept slightly moist. A single post-fumigation treatment of plants with an alkaline bath increased the kill.

DISCUSSION.—The results of the tests here reported indicated that methyl bromide at standard dosages was lethal to larvae of the artichoke plume moth inside the leaf petioles. In many cases considerable injury to the plants resulted; this did not appear immediately after treating but manifested itself in from 10 to 20 days following their planting. The nature of the effects on the plants was not regarded as being of a mechanical nature but, rather, chemical or physiological. The most favorable program was that in tests 19 and 20 where, at a 20″ vacuum, a dosage of 1 pound $CH_3Br$ per 1,000 cu.ft. and an exposure of 120–150 minutes, a kill of 98 to 99 per cent of the larvae was recorded 48 hours after treatment, the surviving larvae dying in from 2 to 12 days. The atmospheric tests showed a perfect kill of larvae, but the long exposures gave a very high mortality of the plants.

It was not possible to regulate temperature in these tests, which would have been very desirable, but there seemed to be little difference in the results within the ranges of temperature recorded.

A single test with eggs of the plume moth, using $2\frac{1}{2}$ pounds per 1,000 cu. ft., temperature 76 degrees F., and a 90 minute exposure, gave a perfect kill. Although no special tests were run on pupae no emergence was recorded from those encountered in the larval counts.

The treatment of plants prior to and after fumigating was given some attention, and it seemed evident from the tests that the plants should not be kept too wet or too dry. With plants of this nature there is often some mortality if they are not planted soon after their separation from the main plant and so, in fumigation work, it would be desirable to treat them immediately after separation and set them out promptly. Future tests should include fumigation of the entire plants in the field before division, as some plant injury may be avoided in this way.

SUMMARY.—The artichoke plume moth, *Platyptilia carduidactyla* (Riley) is spread primarily as larvae in artichoke planting stock where they are, for the most part, internal borers in the leaf petioles. Methyl bromide, in vacuum fumigation tests, was found to give practically a perfect kill of the larvae within the plants at standard dosages. No immediate injury to the plants after treatment was found, but in from 10 to 20 days a noticeable retardation of growth was recorded with death often following. The injury to the plants was not regarded as being of a mechanical nature, but rather chemical or physiological. A delayed kill of the larvae was found in certain cases with death taking place in from 2 to 14 days. The most satisfactory treatment giving a high kill of larvae with minimum injury to the plants was found in the vacuum fumigation treatment using a reduced dosage of 1 pound per 1,000 cu. ft., exposure of 2 to $2\frac{1}{2}$ hours and a temperature of from 72 to 76 degrees F. Atmospheric exposures could not be recommended because of the increased injury to the plants.

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# Seasonal History of Hop Pests on Oregon Hops During 1938

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The Common Red Spider, *Tetranychus telarius* (Linn.)—The seasonal history of the common red spider was studied by making periodical population counts on hop foliage at the entomology experimental hop yard, Corvallis, Oregon. Two different sets of data were collected. Ten leaves from each hop vine of a one-half acre block were selected at random and the number of leaves infested as well as the number of red spiders per leaf were counted or estimated as accurately as possible. These counts were made every ten days and started when red spiders were first found on the hop foliage. The percentage of leaves infested was considered as a measure of red spider distribution and the number of spiders per leaf was used as a measure of population density. Over 4,500 hop vines were examined during the season in the collection of these data.

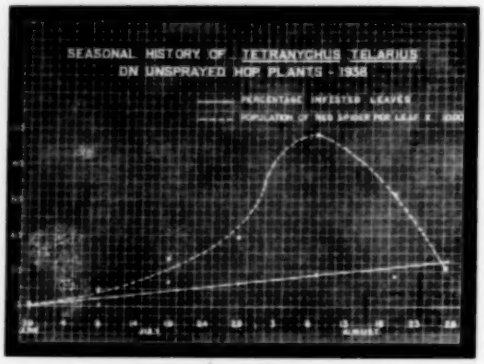


Fig. 1.—Seasonal history of *Tetranychus telarius* on unsprayed hop plants in 1938.

The seasonal development of the red spinder on hops in Oregon normally begins during the early part of June and slowly increases to reach a peak of population density during the latter part of September. Considerable damage is done to the maturing crop at this time of the year.

The seasonal development on untreated hop vines is shown graphically in figure 1. Density figures are magnified 1,000 times in order to show the general slope of the curve. The peak of red spider population occurred about the middle of August during 1938. The summer months were hot and dry and generally considered very favorable for red spider development.

Biological factors are credited with holding the red spider in check during 1938. Time did not permit a detailed biological study, but *Chrysopa californica* Coq., *Hippodamia convergens* Guer., *Hippodamia parenthesis* Say, and *Hippodamia oregonensis* Cor. were found in considerable abundance feeding on the red spider and the hop aphid. Hops were harvested during the middle of September and by this time red spiders had almost entirely disappeared from unsprayed hop vines.

The seasonal development of the red spider on a "baby" (one year old) hop plant is of some interest and is shown in figure 2. This plant was located in the extreme southwest corner of the experimental block. Very early in the spring 100 per cent of the leaves of this vine were infested and this rate of infestation continued until the beginning of August at which time a slight reduction was noted. Red spiders had reached their maximum density by July 19 and began to decline in numbers very rapidly. This plant was treated with an oil spray on August 2 and the ultimate effect of this introduced factor is a matter of conjecture.

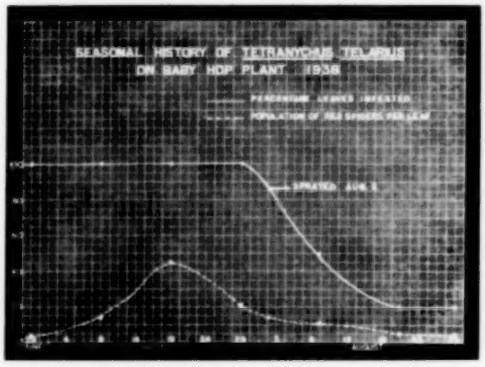


Fig. 2.—Seasonal history of the red spider on a baby hop plant in 1938.

The Hop Aphid, *Phorodon humuli* Schrank. Data on the seasonal develop-

ment of the hop aphid was collected in a similar manner and at the same time as that of the red spider. Spring migrants of this aphid normally appear on hop foliage about the middle of May and the rate of increase is generally slow during the cool spring months. They reach the peak of their abundance about harvest time which normally occurs from the middle to the latter part of September. The secretion of honeydew promotes the development of sooty mould, *Cladosporium* sp., at this time and greatly lowers the market value of the maturing crop.

The hop aphids were first noted on hop foliage on May 23, 1938. They remained few in numbers until the latter part of June when a slight increase in population density was noted. Biological factors began holding them in check at this time and by harvest time very few aphids could be found. Populations were not of sufficient magnitude at any time during the season for conducting insecticidal tests. The seasonal development of the hop aphids on untreated hop vines is presented graphically in figure 3. The density of aphid population is magnified 1,000 times in order to show the general slope of the curve.

THRIPS.—Three species of thrips were taken from the entomology experimental hop yard at Corvallis, Oregon, July 30, 1938. These were determined by Dr. Floyd Andre of the Bureau of Entomology and Plant Quarantine, United States Department of Agriculture, as *Aeolothrips melaleucus* Haliday, *Frankliniella moultoni* Hood, and *Thrips tabaci* Lindeman.

A review of literature shows that *A. melaleucus* has been taken but twice in North America. Ross and Putman[1] observed a few nymphs attacking red spider in the field and under experimental conditions the nymphs fed also on Oriental fruit moth eggs. Moulton[2] captured this species of thrips at Vernon, British Columbia. This record of *A. melaleucus* on Oregon hops apparently marks the first time this species has been taken in the United States. It was not present in large numbers, and its biological control value is somewhat doubtful.

*F. moultoni* Hood is quite common in California, but was taken in Oregon for the first time in 1938. This species and *T. tabaci* are known to be vectors of certain virus diseases and may contribute to the virose symptoms which are sometimes noted in many hop yards throughout the Willamette Valley. Decided silvering of hop foliage in 1938 was attributed to *T. tabaci* and/or *F. moultoni*. It is thought that the reddening or russeting of immature hop clusters which is commonly attributed to moisture or fertilzer factors may be the result of the attacks of these thrips.

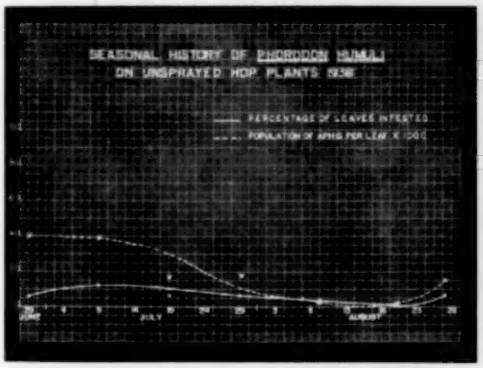


FIG. 3.—Seasonal history of the hop aphid on unsprayed hop plants in 1938.

The omnivorous leaf tier, *Cnephasia longana* Haw., frequently causes considerable damage to hop yards which are located in close proximity to flax fields. Damage is caused by larvae which feed on and destroy the terminal buds of the hop vine. Lateral shoots develop at the points of injury and result in additional labor costs to the practice of stringing hop vines.

The larvae of the mourning cloak butterfly, *Nymphalis antiopa* Linn., have occasionally been reported feeding on nettles, but it was taken, apparently for the first time on hops, near Corvallis, Oregon, in 1938. It is thought that this was only a chance occurrence but ten hop plants were completely defoliated before the larvae were exterminated by the grower.

[1] 46 Ann. Rept. Ent. Soc., Ontario, 1933.
[2] Canad. Ent. 61, 1929.

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THE SWEETPOTATO weevil restrictions of the State Plant Board of Mississippi were lifted from 64 Texas counties in an amendment of Rule 24-A, which became effective November 4, 1939. No change was made in regulated areas now established in other States.

# Pea Aphid Control Experiments in Oregon

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Introduction.—The experimental program in Oregon for the control of the pea aphid in 1936, 1937, and 1938 was carried on entirely in the coastal area, at Astoria. The trials were made on trellis peas grown on the experimental farm at the John Jacob Astor Experiment Station. These tests were made possible through the active cooperation and helpful suggestions of Mr. H. B. Howells, superintendent of this experiment station. The same plot arrangement and the same method of measuring populations were used during 1936, 1937, and 1938, so, in order to condense this report, only the plot arrangement and tabulated data obtained during 1938 will be considered. Liquid insecticides were used primarily in 1936, although preliminary tests of rotenone bearing dusts with a wetting agent were initiated. In 1937 only one liquid spray test (rotenone) was undertaken, dust insecticides being used in all other tests. The liquid insecticides giving most promise were nicotine, rotenone, and *Loro*. Of these, the liquid rotenone spray proved the most effective. This rotenone spray contained rotenone, 1 part in 12,500 parts of water, (cubé or derris, 4 per cent, 1.666 lbs. in 100 gallons) and a wetting agent (*Aresket 240*, 1 part in 440 parts). *Loro* caused severe buring of the foliage.

Plot Arrangement.—The peas were grown in rows about 180 feet long and 5.5 feet apart. The planting was divided into 188 individual plots. Each replica consisted of three rows 15.5 feet long. All tests were in replica of four; making a total of 47 test plots. Each test plot consisted of 186 linear feet of row, or 1/43 acre. The plots were arranged in a modified Latin square system with every 8th plot used as a check except that plot 44 also was left as a check. This arrangement permitted 41 different treatments.

Population Measurements.—The aphid population was measured by counts of aphids on plant tips. A plant tip was considered to be that part of the plant down to and including the first open stipule. About fifty plants were examined in the center row of each individual plot and the number of aphids found, the number of tips examined, and the number of tips infested, recorded. The counts were made by beginning two or three feet inside the plot from the divisions between plots and examining every plant until the required number had been examined or until a distance of two or three feet from the end of the plot had been reached. This method prevented the selection of tips by the person making the count. The first count was made July 25 to 27, before any dust was applied and when the plants were between 8 and 14 inches tall. The remaining five counts were made just following and just preceding each dust application. The last count was made on September 1 to 4 when the plants had attained a height of about 6 feet. During the season more than 1,000 tips were examined on each test plot. No two successive counts were made by the same person on the same plot. This arrangement was to reduce the variation due to the personal equation. Since it required three days to make a count over the entire planting, every third row of plots was counted each day to reduce the variation between plots caused by the lapse of time between the beginning and end of each counting period. To reduce the variation due to fatigue of those making counts, the examination was begun in different parts of the planting on different days.

The results are based on the mean number of aphids per tip for the season after the first dust application. The data were subjected to an analysis of variance using the *t* test as outlined by Huber and Sleesman[1] (1935). Counts made following the various treatments have been analyzed but show no marked difference from the mean of the season, so are not included here.

Dust Applications.—The dust was applied in all cases with a small Root hand duster. The required amount of dust was weighed out for each plot three or four hours before each application, placed in a paper bag, and marked with the plot number. The person operating the duster moved along the row at a uniform speed and adjusted the machine so that each plot was treated twice to give a uniform treatment to all parts of each plot. By

[1] Jour. Econ. Ent. 28 (1): 70.

previously weighing out the dust for each plot, the exact amount per acre could be applied. The applications were always made at night since there is too much wind to use a hand duster during the day in the region of the tests. The amount used per acre was 20 lbs. for the first application when the plants were 8 to 14 inches tall, and 40 lbs. for the two subsequent applications, except for the special "amount per acre" trials. The dates of application were July 28, August 14 and August 25.

The insecticides used included rotenone, nicotine, pyrethrum and *Loro*.[2] The dusts were all mixed on July 9, 10 and 11 in amounts sufficient to permit four dustings of each plot. A churn containing about 20 smooth rocks was used to mix the dust. The mixed dusts were stored in a dark cool place and not exposed to the air, light, or extreme heat except when the portion for each plot was being weighed out for application. The remainder of each mixture was stored in air-tight cans for trials next season to test for deterioration.

Talc was used as the carrier for all tests reported here with the exception of plot 13 where nicotine sulfate was used with hydrated lime. Diatomaceous earth was used for a comparison with talc but the results are not significantly different from those obtained when talc alone was used. The only wetting agent used was *Vatsol OS*.[3]

TESTS MADE.—The combinations of insecticides and various experimental trials conducted during the 1938 season follow:

1. .75 per cent rotenone with wetting agent 1, 2, 3, and 4 per cent.
2. 3 per cent wetting agent with rotenone .25, .50, and .75 per cent.
3. .50 per cent rotenone and 3 per cent wetting agent with nicotine .5, 1 and 2 per cent.
4. Nicotine 2 per cent and wetting agent 3 per cent.
5. Nicotine 2 per cent and hydrated lime.
6. *Agicide* (rotenone .198%).
7. *Loro* 2 per cent with rotenone .75 and .50 per cent.
8. Rotenone .75 per cent and wetting agent 3 per cent at 20, 40 and 60 lbs. per acre.
9. Rotenone .75 per cent and wetting agent 3 per cent applied at 1, 2, 3 and 4 week intervals.
10. Rotenone .25 per cent and wetting agent 1 per cent applied at 40, 60, and 120 lbs. per acre.
11. Wetting agent (*Vatsol OS*) 3 per cent.
12. Rotenone .75 per cent.
13. Rotenone .75 per cent wetting, agent 3 per cent plus pyrethrum stems 25, 50 and 100 per cent of carrier.*
14. Rotenone .75 per cent plus cotton-seed oil 1, 2, 4 and 6 per cent.
15. Rotenone .75 per cent plus each of the following oils at 4 per cent: castor oil, peanut oil, cocoanut oil, olive oil, and neatsfoot oil.
16. Rotenone .75 per cent, wetting agent 3 per cent, and cotton-seed oil 4 per cent.
17. Rotenone .50 per cent, wetting agent 2 per cent, and cotton-seed oil 4 per cent.

RESULTS.—Table 1 presents the results of three applications of each of the various insecticides. The figures given are the means of five counts made on each replica during the period from August 3 to September 4. The percentage control is based on the check plots which had a mean aphid count of 35.55 aphids per tip. At odds of 19 to 1 the dust containing rotenone and wetting agent in the amounts used in plot 3 is not superior to the dust containing nicotine 2 per cent in hydrated lime used on plot 13. The 1937 results, however, do indicate a significant difference between control effected by the rotenone-wetting agent combinations and by nicotine. Although the difference in 1938 is not statistically significant, there is a marked trend in favor of rotenone-wetting agent combinations.

Both the rotenone-wetting agent combination plus pyrethrum stems and *Loro* plus rotenone gave good kills and in general showed significantly better control than the rotenone-wetting agent combination. There was a slight burn caused by the dusts containing *Loro*. The additional cost of the pyrethrum stems and *Loro* in these dusts reduced their desirability.

A rotenone-oil combination in a dust form was tried. The low cost of this dust and its apparent effectiveness gives much promise. All the rotenone-oil dusts, with one exception, showed a significant advantage over the rotenone-wetting agent dust. There was no evidence of burn on the plants and no difficulty was experienced in application.

OIL DILUTION TESTS.—Cotton-seed oil was used to determine the most efficient amount of oil to use in the dust mixtures. The percentages of oils used were 1, 2, 4, and 6, all with .75 per cent rotenone. Six

[2] Aliphatic thiocyanates 50%, fatty acid sulfonates 40%, and water 10%.

[3] Sodium salt of an alkyl naphthalene sulfonic acid, practically 100% pure.

* The pyrethrum stems contained .05% pyrethrins so that the mixed dusts contained .0105%, .0205% and .042% pyrethrins respectively.

**Table 1.—A comparison of the performance of the various insecticides and combinations used in 1938 trials. All dusts were of a talc base and applied at 20 and 40 lbs. per acre on the same dates.**

| Plot No. | Treatment | Aphids per Tip Rep. 1 | 2 | 3 | 4 | Total | Mean | Per Cent Control |
|---|---|---|---|---|---|---|---|---|
| 3 | Rotenone .75%, wetting agent 3% | 6 | 9 | 9 | 16 | 40 | 10.00 | 72 |
| 13 | Nicotine 2% | 19 | 8 | 16 | 14 | 57 | 14.25 | 60 |
| 14 | *Agicide* | 13 | 8 | 8 | 10 | 39 | 9.75 | 73 |
| 15 | Rotenone .75%, *Loro* 2% | 3 | 6 | 3 | 3 | 15 | 3.75 | 89 |
| 20 | Rotenone .50%, *Loro* 2% | 6 | 5 | 8 | 5 | 24 | 6.00 | 83 |
| 27 | Rotenone .75%, cotton-seed oil 4% | 5 | 6 | 4 | 4 | 19 | 4.75 | 87 |
| 33 | Rotenone .75%, cotton-seed oil 4%, wetting agent 3% | 4 | 2 | 3 | 2 | 11 | 2.75 | 92 |
| 34 | Rotenone .75%, castor oil 4% | 6 | 9 | 2 | 2 | 19 | 4.75 | 87 |
| 35 | Rotenone .75%, peanut oil 4% | 3 | 4 | 6 | 10 | 23 | 5.75 | 84 |
| 36 | Rotenone .75%, cocoanut oil 4% | 2 | 2 | 2 | 12 | 18 | 4.50 | 87 |
| 37 | Rotenone .75%, wetting agent 3%, pyrethrins .0105% | 5 | 6 | 5 | 8 | 24 | 6.00 | 83 |
| 38 | Rotenone .75%, wetting agent 3%, pyrethrins .0205% | 6 | 4 | 5 | 4 | 19 | 4.75 | 87 |
| 39 | Rotenone .75%, wetting agent 3%, pyrethrins .042% | 3 | 4 | 2 | 2 | 11 | 2.75 | 92 |
| 42 | Rotenone .75%, olive oil 4% | 3 | 3 | 3 | 1 | 10 | 2.50 | 93 |
| 43 | Rotenone .75%, neatsfoot oil 4% | 4 | 4 | 4 | 1 | 13 | 3.25 | 91 |

Difference between means necessary for significance at odds of 19−1 = 4.58; 49−1 = 5.87; 99−1 = 6.93.

per cent oil was used as a maximum because it was assumed that a dust containing more would not blow through the machine easily. No difficulty was experienced in applying any of these dusts. Table 2 presents the percentage of oil, the counts for each replication, and the mean number of aphids per tip for all counts of each plot. On the basis of the difference between means, there is no advantage of 2 per cent oil over 1 per cent, or of 6 per cent over 4 per cent, but there is a significant difference at 49 to 1 odds between the 4 per cent or 6 per cent over the 1 per cent or 2 per cent oil plots.

**Table 2.—A comparison of the relative effectiveness of dust mixtures containing rotenone .75 per cent with various cotton seed-oil contents.**

| Plot No. | Treatment | Aphids per Tip Replica No. 1 | 2 | 3 | 4 | Total | Mean | Per Cent Control |
|---|---|---|---|---|---|---|---|---|
| 25 | Oil 1% | 10 | 9 | 6 | 5 | 30 | 7.50 | 79 |
| 26 | Oil 2% | 8 | 9 | 7 | 8 | 32 | 8.00 | 77 |
| 27 | Oil 4% | 5 | 3 | 4 | 4 | 19 | 4.75 | 87 |
| 28 | Oil 6% | 3 | 7 | 4 | 3 | 17 | 4.25 | 88 |

Difference between means necessary for significance at odds of 19−1 = 2.15; 49−1 = 2.76; 99−1 = 3.26.

Not enough space was available to use oils of plant, animal, and mineral origin. Accordingly only five plant oils and one animal oil were used. Table 3 gives the results of these trials. There is no significant difference between the means of the various plots. Combinations of rotenone, oil, and wetting agent were tried but produced little or no better kill than the oil-rotenone mixtures (see table 1, Plot 33).

DILUTIONS OF WETTING AGENT.—Four sets of plots were arranged for tests to determine the most efficient dilution of wetting agent. These plots each recieved the three applications of dust at 20 lbs. per acre for the first application and 40 lbs. for the two subsequent dustings. Table 4 gives the results of these tests. It may be seen that there is no significant difference between the means. These data agree with the 1937 results in that they indicate no significant differences between wetting agent concentrations.

OTHER TESTS OF DUSTING MATERIALS.—Plots to test the relative effectiveness of concentrations of rotenone dusts bear-

**Table 3.—A comparison of the relative effectiveness of dust mixtures containing Rotenone .75 per cent plus 4 per cent of various oils.**

| Plot No. | | Aphids per Tip Replica 1 | 2 | 3 | 4 | Total | Mean | Per Cent Control |
|---|---|---|---|---|---|---|---|---|
| 27 | Cotton-seed oil | 5 | 6 | 4 | 4 | 19 | 4.75 | 87 |
| 34 | Castor oil | 6 | 9 | 2 | 2 | 19 | 4.75 | 87 |
| 35 | Peanut oil | 3 | 4 | 6 | 10 | 23 | 5.75 | 84 |
| 36 | Cocoanut oil | 2 | 2 | 2 | 12 | 18 | 4.50 | 87 |
| 42 | Olive oil | 3 | 3 | 3 | 1 | 10 | 2.50 | 93 |
| 43 | Neatsfoot oil | 4 | 4 | 4 | 1 | 13 | 3.25 | 91 |

Difference between means necessary for significance at odds of 19−1 = 5.33; 49−1 = 6.85; 99−1 = 8.08.

**Table 4.—A comparison of results obtained by the application of dust mixtures containing .75 per cent rotenone and various dilutions of wetting agents.**

| Plot No. | Treatment | Aphids per Tip | | | | | | Per Cent Control |
|---|---|---|---|---|---|---|---|---|
| | | Replica No. | | | | Total | Mean | |
| | | 1 | 2 | 3 | 4 | | | |
| 1. | Wetting agent 1% | 10 | 10 | 13 | 15 | 48 | 12.00 | 66 |
| 2. | Wetting agent 2% | 7 | 9 | 10 | 13 | 39 | 9.75 | 73 |
| 3. | Wetting agent 3% | 6 | 9 | 9 | 16 | 40 | 10.00 | 72 |
| 4. | Wetting agent 4% | 3 | 6 | 7 | 18 | 34 | 8.5 | 76 |

Difference between means necessary for significance at odds of 19 − 1 = 3.69; 49 − 1 = 4.75; 99 − 1 = 5.60.

ing .25 per cent, .50 per cent, and .75 per cent in combination with 3 per cent wetting agent were set up. The means for the plots were 14, 13, and 10 aphids per tip, respectively. A difference of six between the means is necessary for significance at 19 to 1 odds. These results also agree in general with what was found in the 1937 tests.

A series of plots were treated with dust containing .5 per cent rotenone and 2 per cent wetting agent plus .5 per cent, 1 per cent, and 2 per cent nicotine. These were compared to plots treated with rotenone .5 per cent and wetting agent 2 per cent as well as plots treated with nicotine 2 per cent and wetting agent 2 per cent. There was no significant difference between any of these treatments. Less control was obtained by the dusts containing the greater amounts of nicotine.

Three plots were treated with dust containing .25 per cent rotenone and 1 per cent wetting agent. The dust was applied at 40, 80, and 120 lbs. per acre. The plot treated with the heaviest application received the same amount per acre of insecticide and wetting agent as did plot 3 treated with dust containing .75 per cent rotenone and 3 per cent wetting agent. This was done to test the possibility that a cheaper dust applied at a heavier rate per acre might give a more efficient control because of a more thorough coverage. The results indicate that there is no advantage in this method. The best control obtained in these trials was slightly poorer than that obtained from a more concentrated dust.

Dust containing rotenone .75 per cent and wetting agent 3 per cent was applied at intervals of 1, 2, 3, and 4 weeks. The results of these trials are given in table 5. It will be seen that the difference between the one and two week interval dustings is

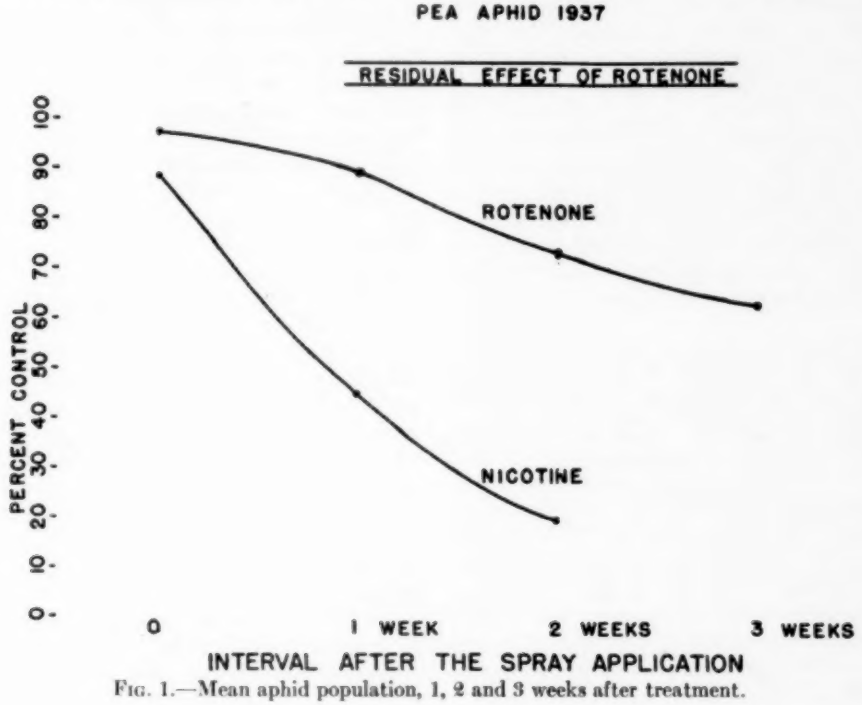


FIG. 1.—Mean aphid population, 1, 2 and 3 weeks after treatment.

not significant, but the differences between the one and three or four week intervals and the two and four week intervals are definitely significant. Similar results were obtained in 1937.

**Table 5.—A comparison of the control obtained by various intervals of application with a dust containing .75 per cent rotenone and 3 per cent wetting agent.**

| Plot No. | Treatment Interval | Aphids per Tip: Replica No. 1 | 2 | 3 | 4 | Total | Mean | Per Cent Control |
|---|---|---|---|---|---|---|---|---|
| 18 | One week | 5 | 7 | 4 | 4 | 20 | 5.00 | 86 |
| 3 | Two weeks | 6 | 9 | 9 | 16 | 40 | 10.00 | 72 |
| 21 | Three weeks | 9 | 18 | 14 | 20 | 61 | 15.25 | 57 |
| 22 | Four weeks | 14 | 10 | 22 | 31 | 77 | 19.25 | 46 |

Difference between means necessary for significance at odds of 19−1=8.29.

LIQUID SPRAY TESTS.—In 1936 the number of applications test was made to determine the frequency with which each liquid insecticide should be applied to effect a satisfactory control. Plots were arranged so that for each insecticide, one plot would receive sprays at 1 week intervals, one plot at 2 week intervals, one plot at 3 week intervals, and one at 4 week intervals. Aphid counts were made on each of the plots before each spray was applied. For peas sprayed at weekly intervals the rotenone showed a total of 12 aphids and nicotine 94 aphids; for the two week interval rotenone showed 2 aphids and nicotine 290 aphids; for the three week interval rotenone showed 141 aphids and nicotine 1,993 aphids; and for the four week interval rotenone showed 279 aphids and nicotine 3,886 aphids. This indicates that rotenone, 1 to 10,000, applied at intervals of four weeks produces as good control as nicotine 1 to 660 applied at two week intervals.

**Table 6.—A comparison of the control obtained by the application of different amounts per acre of dust containing rotenone .75 per cent and wetting agent 3 per cent.**

| Plot No. | Treatment Lbs. per Acre | Aphids per Tip: Replica No. 1 | 2 | 3 | 4 | Total | Mean | Per Cent Control |
|---|---|---|---|---|---|---|---|---|
| 17 | *10 and 20 | 16 | 19 | 13 | 14 | 62 | 15.5 | 56 |
| 3 | *20 and 40 | 6 | 9 | 9 | 16 | 40 | 10.0 | 72 |
| 19 | *30 and 60 | 5 | 5 | 9 | 11 | 30 | 7.5 | 79 |

* The first figures (10, 20 and 30) indicate the amount used for the first application when the plants were 8 to 14 inches tall. The 20, 40 and 60 pounds were used subsequently.

Difference between means necessary for significance at odds of 19−1=5.75; 49−1=7.39; 99−1=8.71.

The relative costs of the two sprays calculated on the basis of results obtained is as follows:

| | | |
|---|---|---|
| **Cost of nicotine spray** | | |
| 1½ lbs. nicotine sulfate 40% at $1.00 | | $1.50 |
| 1½ lbs. *Aresket 240* at .40 | | .60 |
| 2 lbs. fish oil soap at .10 | | .20 |
| Cost per 100 gallons of spray | 2.30 | |
| Cost per acre (300 gals. of spray for first application) | 6.90 | |
| Cost per acre (600 gals. of spray for second application) | 13.80 | |
| Total Cost per Acre | 20.70 | |
| **Cost of rotenone spray** | | |
| 2 lbs. cubé at .50 | | $1.00 |
| 1½ lbs. *Aresket 240* at .40 | | .60 |
| 2 lbs. fish oil soap at .10 | | .20 |
| Cost of 100 gals. of spray | 1.80 | |
| Cost per acre (only the first application needed) | 5.40 | |

AMOUNT OF DUST PER ACRE.—A test to determine the most efficient rate of dust application per acre was arranged. The results of both the 1937 and 1938 trials indicate that about 60 lbs. of dust per acre per application produces the most efficient kill. The 1937 trials include amounts up to 80 lbs. per acre and indicate that 50 to 60 lbs. was equally effective. The results of the 1938 trials are given in Table 6.

After the dust application of August 14, counts were made daily beginning on August 16 and continued for four days with a fifth count on August 25 to determine the rate of kill for both rotenone-wetting agent and rotenone-oil dusts. The plots used were 3 and 43. The greatest kill was noted on the third day after application for the rotenone-wetting agent dust and on the fourth day for the rotenone-oil dust. The difference between means was significant in both cases.

SUMMARY.—The results of pea aphid control experiments reported herein are principally those obtained during the 1938 season where only dusts were used. All applications were made by means of hand dusters on trellis peas in the coastal area of Oregon. The plot arrangement was a modified Latin square in replica of four. Each replica consisted of three rows 15.5 feet long with the rows 5.5 feet apart.

Populations were measured by counts of aphids on plant tips and reduced to mean number of aphids per tip for comparison. Five counts were made on each plot during the season.

Insecticides used included rotenone, nicotine, pyrethrum, and *Loro*. Talc was

used as the carrier for all the insecticides except nicotine where hydrated lime was used.

A rotenone dust containing 4 per cent of a vegetable or animal oil appears to have possibilities of producing a more effective kill at less cost than other dust combinations tested. Rotenone dust with a wetting agent did not give as good control as did rotenone and oil. Nicotine and pyrethrum dusts were inferior to the rotenone-oil dusts. *Loro*-rotenone dusts gave good kills but produced a slight burn on the tender plant tips.

Spray tests conducted prior to 1938 indicate that a satisfactory control may be obtained on peas grown on trellises by the use of a spray containing rotenone, 1 part in 10,000, wetting agent (*Aresket 240*) 1 part in 660, and fish oil soap 1 part in 440 applied at about 300 gallons per acre.

# Studies of Factors Affecting Package Bees

J. E. ECKERT,[1] *University of California, Davis*

In certain sections of the United States, particularly in the Sacramento Valley of California, and in portions of Alabama, Louisiana, Mississippi and Texas, environmental conditions are favorable for honeybees to increase their numbers early enough in the spring to permit the shipment of surplus bees in screened cages to more northerly points in the United States and to Canada. These surplus bees are used to establish new colonies for honey production during the summer months or to pollinate fruit trees. In many of the northwestern and Rocky Mountain states, and in most of the provinces of Canada where winters are severe, it has been found practical to kill the colonies of bees at the close of the honeyflow and to restock the hives with package bees the following spring.

The production, shipment and installation of package bees involve many factors not commonly met with in the more routine beekeeping practices. Queens must be reared in quantity, before the normal swarming season, when weather conditions are not always favorable for proper mating. The bees are shaken from combs into screened cages through queen excluders—to sift out the drones and to exclude queens—and a young queen is included with each 2, 3 or 4 pound lot of bees. Where the bees and the queen in a package come from the same colony, the queen may be shipped loose in the package; otherwise, she is caged in a queen cage which is then hung inside and near the top of the larger cage. Sugar syrup made of granulated sugar and water provides the caged bees with food while in transit.

Package bees are transported either by express or by motor truck and are installed, generally, within 3 to 5 days after they are shaken from their hives. Environmental conditions of heat and cold may vary greatly in transit and between the place of origin and the final destination. A careful driver with suitable equipment can regulate the temperature in a truck more readily than is done at present when bees are shipped by express but, with proper care enroute, package bees can be shipped in good condition by either means of transportation. A great majority of the many thousands of packages of bees involved in this industry are shipped by railway express but an increasing number each year is being hauled by motor transport.

Various methods are used to establish package bees in hives, the method chosen often being governed by prevailing weather conditions. Sometimes package bees must be installed during snow storms or when temperatures are so cold as to cause bees to cluster tightly in the shipping cage or hive. At other times weather conditions are favorable enough to permit bees to fly and under such conditions bees from one hive may drift to another in sufficient numbers to change materially the number of bees in the hives affected.

Environmental conditions affecting

[1] The writer wishes to acknowledge the efficient assistance and cooperation rendered by Mr. S. O. Hillerud then Provincial Apiarist of Alberta and also Mr. R. H. Hawthorne, of Taber, Alberta, in the furtherance of this study. The production records of package bee colonies submitted herein were secured by Mr. Hillerud and Mr. Hawthorne. The writer further wishes to express his appreciation to the Department of Agriculture in Alberta for enabling Mr. Hillerud to assist in this work. Acknowledgment of the financial support given this project by the California Bee Breeders Association is also hereby gratefully given.

plant growth, nectar secretion and pollen production are seldom the same for any given location in successive years so that the conditions influencing the development of a colony and the production of honey are subject to wide fluctuations.

One of the principal problems of the honey producer receiving package bees is connected with the failure of some of the queens to maintain brood rearing sufficient to build up strong colonies for the honey flow. The results are generally manifested in two ways: (1) The original queen may be superseded by one the bees have reared; or (2) the queen may continue during the season to produce sufficient brood to satisfy the normal requirement of the colony but too little to make the stand strong enough to be an economical producer of honey. In cases of supersedure, the young queens are not always mated and so may become drone layers. The loss of brood during the supersedure process often seriously reduces the strength of the colony later in the season and thus affects the amount of honey produced.

EXPERIMENTAL METHODS.—In 1935 a cooperative project was outlined between the University of California at Davis and the provincial apiarist of Alberta, Mr. S. O. Hillerud, to study factors which might cause these two deterrants to the efficient operation of package bees for honey production. A study of factors that obtained during the preparation, shipment and installation of packaged bees was made by the writer during the spring of 1935, the results of which were published in this journal[2] as well as in the *Canadian Bee Journal*.[3]

From 1935 to and including 1938, package bees from 9 to 15 producers were shipped by express from California to Taber or Coaldale, Alberta, at the same time each spring and were installed under uniform conditions each year. The shippers were instructed to prepare 3-pound packages in a normal manner and to use the California 4-package method of crating the packages. By this means a variety of factors that would ordinarily be included under commercial conditions such, as different strains and races of bees, the personal factor in the rearing of queens and in preparing the package for shipment, and environmental influences in transit were incorporated in the experimental packages.

The identity of the producer, with but a few unavoidable exceptions, was concealed during each season by assigning a number to each strain or unit of bees. Four or more colonies of bees from each strain comprised a unit. The colonies were so distributed in different locations in the experimental apiary as to reduce as much as possible the effect of wind on the drifting of bees from one hive to another. Windbreaks were also erected to offset this factor.

When the packages were received in Canada, the exact condition of each package was noted and the bees were installed by the following methods:

In 1935, the hives were prepared with five combs, one of pollen, one of honey, one partially filled with honey, one empty comb and one partially filled with honey. The queen cage was placed on top of the frames after the perforated metal had been punched in and the hole filled with softly granulated honey. A portion of the bees was shaken on top of the queen cage and the package then set in the hive, top side up. A burlap sack and a wooden cover closed each hive. Two days later the package was removed and an open pail filled with straw and containing 10 pounds of heavy sugar syrup was set in the hive beside the frames. Five days later this feed can was removed and two empty combs, and one partially filled with honey and another with pollen were added to each hive to make up the complement of 9 frames. Each colony was established with at least 180 square inches of pollen and 10 to 15 pounds of honey.

In 1936, 1937, and 1938, the bees were installed on 9 combs, arranged as listed above, by inverting the package on top of the frames inside an empty hive body after a portion of the bees had been shaken over the queen cage, placed as in the first method, above. A 10-pound friction-top feed pail of sugar syrup was placed on top of the frames in one corner and a burlap sack tucked over all to keep in the warmth of the cluster. An outer cover closed the hive. Five to seven days later the feeder can, cage, queen cage, and hive body were removed and the combs

[2] Eckert, J. E., 1936. The preparation, shipment and installation of package bees. JOUR. ECON. ENT. 29(5): 877–85. 1 illus.
[3] Eckert, J. E., 1936. Observation on the preparation and shipment of package bees. Can. Bee Jour. 44(1): 5–7; (2)29–31; (3)59–60.

checked for eggs to determine whether a laying queen was present.

In all four years the weather was cold, with snow flurries in 1935 and 1938, at the time the bees were installed.

During each season, the colonies were observed regularly for the amount and condition of the brood, for queen cells and swarming or supersedure tendencies and for the amount of honey produced. The queens were caged during the second or third week in August to permit the brood to emerge before the close of the honeyflow when the colonies were killed. The cent supersedure of queens had been received in former years, and thus made supersedure an important problem throughout the province, no such situation developed in colonies produced by the experimental packages. The variation in production by colonies of the same strain as well as between the different strains was so outstanding that this characteristic received the most attention in the general absence of supersedure difficulties. Some of the colonies built up rapidly while others lagged behind throughout the season. Table 1, column

**Table 1.—Data on package bee colonies.**

| | Average Pounds of Honey Produced per Colony | | | | | | | Average Pounds of Dead Bees per Colony at Close of Honeyflow | | Total Square Inches of Brood per Colony[1] | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Group | 1935 | 1936 | Variation within group | 1937 | Variation within group | 1938 | Variation within group | 1935 | 1936 | 1937 | 1938 |
| 1* | 86 | 139 | 146 | 150 | 126 | 245 | 204 | 6.0 | 8.5 | 2336 | 1604 |
| 2* | 127 | 223 | 17 | 160 | 127 | 190 | 166 | 6.0 | 9.0 | 2196 | 1400 |
| 3* | 130 | 216 | 37 | 203 | 94 | 209 | 75 | 6.0 | 8.4 | 2457 | 2405 |
| 4 | 101 | 203 | 150 | 188 | 144 | 156 | 78 | 4.3 | 6.4 | 2437 | 1746 |
| 5* | 115 | 236 | 75 | 196 | 133 | 177 | 117 | 6.0 | 6.8 | 2443 | 1464 |
| 6 | 90 | 196 | 44 | 233 | 159 | 223 | 155 | 5.0 | 6.4 | 2823 | 2174 |
| 7* | 82 | 192 | 114 | 123 | 121 | 236 | 113 | 5.7 | 8.1 | 1675 | 2225 |
| 8 | 123 | 129 | 86 | 267 | 55 | 219 | 221 | 6.0 | 7.4 | 2855 | 2321 |
| 9 | 76 | 172 | 59 | — | — | 211 | 118 | 4.7 | 8.0 | | 2039 |
| 10 | | 161 | 43 | 130 | 190 | 207 | 111 | | 7.1 | 2086 | 1953 |
| 11 | | 205 | 64 | 205 | 225 | 202 | 109 | | 7.8 | | 2130 |
| 12 | | 192 | 58 | | | 197 | 234 | | 7.4 | | 1581 |
| 13 | | 210 | 45 | 184 | 136 | | | | 9.1 | 2093 | |
| 14 | | 207 | 49 | | | | | | 7.6 | | |
| 15 | | 190 | 129 | | | | | | 5.9 | | |
| Grand Averages | 103 | 193 | 74 | 176 | 139 | 206 | 142 | 5.5 | 7.6 | 2340 | 1837 |

* Shippers had same numbers during the four years, otherwise shippers were given the same group numbers as in 1936.
[1] Brood counts were taken on 5/31, 6/15 and 7/28 in 1937 and on 6/11 and 7/28 in 1938.

weight of the bees in each colony was determined in 1935 and 1936. Each colony was operated as a unit, but the total brood or honey production of each strain of bees was averaged for purposes of comparing relative merits of the different strains.

In a number of instances, queens of abnormal behavior were returned to the writer for microscopical examination or further observation. In conjunction with the observations in Canada, an investigation was started at the University of California at Davis to determine the effect of temperature and other factors on the productivity of queens.

VARIATION IN PRODUCTION.—The 1935 shipment of packages was considered as an indicator of future possibilities for observing some of the specific causes of supersedure. While reports of 20 to 50 per

2, gives the average colony production for the various groups or strains in 1935. On the whole, 1935 was below average for honey production in the locality of the experimental apiary and several of the colonies would have been united with others early in the season in normal commercial practice in order to increase the production of the entire yard.

In table 1, certain pertinent data are given to indicate further the great variation that existed not only between the different strains, but also between colonies of the same strain. In 1936, there was an extreme range of from 12 to 150 pounds in the production of honey between colonies of various groups and a range of 105 pounds between the production of the best and the poorest groups. Even greater variations were noted in 1937 and 1938. Neither the strenth of the colony, as in-

dicated by the weight of bees at the close of the honeyflow, nor the total amount of brood during the season gave a satisfactory basis for an explanation of this variation in colony behavior. In fact, it was so evident in all groups but No. 2, table 1, in 1936, that this characteristic was the general rule rather than the exception and undoubtedly was of greater importance in the production of honey than the rather isolated cases of absolute queen failure.

In each year, the productivity of several queens was such as to have justified their replacement, as far as the beekeeper was concerned, but was normal enough for the colonies to continue their activities without the bees attempting to replace the queens. This situation was one of the direct causes of the great variation in the average production of the various groups, as well as between the colonies of each group. Practically every strain had one or more good colonies and as the colonies were grouped so that no two hives of the same strain were placed in the same group this variation in production must have been due largely to some inherent difference in the colonies or strains rather than to such environmental factors as weather conditions, the increase in strength of a colony through drifting, or manipulation.

SOME CAUSES OF SUPERSEDURE.—An examination of queens exposed artificially to cold indicated that their physical condition may be so impaired as to cause reduced productivity, and even drone production. The effect of heat beyond a given tolerance may be likewise destructive. The injury or maiming of queens by the bees, due to excitement brought on by the colony being disturbed under unfavorable circumstances, is a very logical cause of supersedure or reduced productivity. Of 8 queens returned from the experimental yard for observation in 1937, 4 produced satisfactory colonies when introduced in the University apiary, 2 were injured physically sufficiently to have caused their replacement, and 2 showed no physical reasons why they were superseded in Canada and again when introduced into colonies at Davis. Sometimes the injures to a queen such as the loss of a foot segment or injury to the terminal segment of an antenna or an indentation of the abdomen affecting the ovaries are so slight as to escape average observation; and not all injured queens are superseded by the bees. Drone-laying queens from package bee colonies often had viable sperms in the spermatheca, indicating that they had been mated before being placed in the package, but had been injured by cold in a manner that would not permit the spermatheca to function properly in the release of the sperms. The acid glands in such queens are usually dark in color, often black in spots, while the normal appearance of the acid glands of a healthy queen is white and clear. The acid glands of worker bees are likewise impaired when the bees are exposed to unfavorable cold temperatures for definite periods.

SYMPTOMS PRECEDING SUPERSEDURE.—The supersedure of a queen is often preceded by certain symptoms associated with the brood. In a majority of the cases of queen failure observed, followed by attempts at supersedure, varying amounts of drone brood were found in worker cells scattered among normal worker brood. If queen cells were present, the supersedure of the queen was almost certain to follow.

The presence of two or more eggs in a cell, if the eggs are attached to the bottom of the cells and not on the side walls, is not necessarily an indication of a failing queen. When the brood is normal, with no drone brood in worker cells, and with no queen cells in progress, observations have indicated that the queen has reached a higher egg-laying rate than the workers could take care of. Such queens generally produce good colonies. But, when the queen lays irregularly on the side walls of cells and more than one egg to the cell, she is abnormal and will generally be superseded by the bees. This irregularity of placing eggs in the cells may be due to some physical injury the queen has suffered.

PRODUCTION BY REQUEENED COLONIES. When colonies from package bees do not build up rapidly in the spring or lose their queens on installation, beekeepers have been in doubt as to whether they should be requeened or be united with other colonies in order to secure the most honey. In table 2 are shown the results of requeening certain colonies in 1937, in which year the average production of the entire experimental yard was 176 pounds. In 5 out of 10 cases (Colony 13-5-04

was not requeened because of the lateness in the season when the queen failed), the production of the requeened colonies ranged over 100 pounds and in only 3 instances did it fall below 81 pounds. Whether it is more practical to requeen or to unite a colony with another no doubt depends on the availability of the queens when needed as well as on the strength of the colony and the length of the remaining brood-rearing period. In 8 out of the 10 cases observed, it would seem doubtful if the result of uniting the queenless colonies

**Table 2.—Production of requeened colonies in 1937 (colonies were installed May 9).**

| COLONY NUMBER | BECAME QUEENLESS | DATE REQUEENED | HONEY PRODUCTION (pounds) |
|---|---|---|---|
| 7-1-11 | At installation | May 25 | 85 |
| 13-4-36 | May 25 | May 31 | 195 |
| 10-1-12 | May 31 | June 11 | 81.5 |
| 10-5-06 | * | | 54.5 |
| 13-1-10 | May 25 | June 11 | 59 |
| 13-5-04 | *** | | 136 |
| B-1-05 | ** | June 11 | 132 |
| B-3-18 | ** | June 11 | 107.5 |
| X-4-42 | ** | June 11 | 147 |
| 7-2-34 | ** | June 11 | 82.5 |

* Queen cells were started May 25, queen turning to a drone layer. Was not replaced.
** Laying many drone eggs by May 31.
*** Normal brood to May 31, q. cells June 15, nearly all drone brood, July 28. 13-1-10 had laying workers by May 31. Conditions were unfavorable for queen introduced June 11.

or those having failing queens, with others would have increased the honey yield by a like amount.

CONCLUSIONS.—From the data presented herein and from the detailed records of the colonies during the 4 years it was evident that the variation in the relative productivity of the queens and their colonies was far more important than the actual supersedure of queens. It would appear that queen bees and their colonies are just as variable in physical potentialities as are other animals. No two are exactly alike in all characteristics and in the case of the honeybee there is the uncontrollable factor of mating that makes for wide variations within any given strain. Consequently, the problem of the queen breeder is to improve his methods of queen-rearing continually so as to eliminate undesirable characteristics and to breed for high uniformity in production. The honey producer can assist by returning to the queen breeder queens having the most desirable characteristics leading to high yields by maintaining conditions that will tend to promote the greatest aggregate production. Improved methods at the time of installing package bees, such as the feeding of warm syrup to assist the bees in warming up the cold hives, will reduce the ill effects of exposure to cold on queens and worker bees.

The most important symptom preceding the supersedure of queens is the presence of some drone brood in worker cells. This may occur soon after the packages are installed but may not appear until several weeks later. The cause of this failure of queens is not indicated.

# Larval Pests Common to Nests of Bumblebees and Combs of the Honeybee*

V. G. MILUM

The title of this article was suggested by the kindness of the Rev. H. B. Luther of Bingham, Nebraska, who in November 1935, submitted to the writer for identification living larvae that were found feeding in neglected honeybee combs. These pinkish caterpillars somewhat resembled the larvae of the codling moth, *Carpocapsa pomonella* L., which sometimes are found inside bee hives, or in the cracks and crevices or around the cover where they may seek a protected place for pupation if the hives are located near infested fruit trees. Not being recognized as a familiar species infesting combs, the larvae were allowed to pupate, the adults which emerged closely resembling *Ephestia kuehniella* Zell., the Mediterranean flour moth. All of a second group of larvae collected at the original source in Kansas, in March 1936, were dead when received, these having been exposed to the extreme outside temperature of minus 35 degrees F.

For the identification of the adult moths of the first group of specimens as *Vitula edmandsii* Pack., the writer is indebted to Dr. Carl Heinrich who states that "it has habits similar to *Ephestia*,

* Contribution from the Entomological Laboratories of the University of Illinois, No. 201.

the adults being easily confused with *E. kuehniella* because of their similarity superficially, but may be distinguished by the venation of the fore wing, *V. edmandsii* having veins 4 and 5 stalked while in *E. kuehniella* they are united."

This is not the first record of this species infesting combs of the honeybee for the October, 1932, issue of the JOURNAL OF ECONOMIC ENTOMOLOGY (25:946) states that *V. edmandsii* had been found infesting comb honey in storage in Colorado, doing considerable damage by eating cappings, spinning light webs and pupating in empty corner cells. It was in turn parasitized by a wasp, *Nemeritis canescens* Gravenhorst. Although no name was attached to this report credit should probably be given to R. G. Richmond who, in personal correspondence, reported *V. edmandsii* as a pest of comb honey.

Through the kindness of Mr. Harry Hoogstraal, some seventy-one larvae of *Vitula edmandsii* of various sizes were recovered from a nest of the bumblebee, *Bombus impatiens*, six inches in ground, found at Waveland, Indiana, in October, 1938. Still alive in the nest were 58 queens, 39 drones and 10 workers, the rightful inhabitants of the nest. Mr. Hoogstraal informs the writer that one adult resembling *E. kuehniella*, but probably *V. edmandsii* escaped from the nest, no pupae being found. Frison (1926) found moths and pupae as late as October in Illinois. However, this pest, *V. edmandsii*, had previously been found in the nests of bumblebees from which it was originally reared and described by Packard in 1864, and later reported by Franklin (1913) and Frison (1918). It is also listed by Forbes (1923) and Leonard (1926) as a pest of bumblebee nests in New York.

Frison (1926) states that in bumblebee nests, the larvae feed upon wax, pollen and comb. The writer has not attempted to determine the exact food of this species when feeding upon honeybee combs. It is entirely possible that the wax and comb in any type of nest or comb are eaten incidentally by *V. edmandsii* in securing the pollen, if its habits, as suggested by Heinrich, are similar to those of *E. kuehniella* and *E. cautella*, the almond moth. Both of the latter the writer has observed to feed upon the stored pollen and not the refuse of the honeybee brood combs on which three other species may reproduce, either with or without pollen, these being the greater wax-moth *Galleria mellonella* (L.), the lesser wax-moth, *Achroia grisella* Fab. and the Indian-meal moth, *Plodia interpunctella* (Hbn.). The writer has been unable to rear adults of either *E. kuehniella* or *E. cautella* on honeybee brood comb when care is taken to eliminate such protein sources as pollen or dead insects, including the bodies of the parents of the larvae in the culture, whereas in combs containing pollen, thriving cultures may be maintained.

Of the additional species just mentioned as feeding on honeybee combs, Frison (1926) reports *P. interpunctella* as a pest of bumblebee nests in Illinois while Davidson (1894) reported finding *E. kuehniella* in the nests of *B. fervidus* in California. Since *E. cautella* has habits otherwise quite similar to *E. kuehniella*, it may be expected to be found occasionally as a pest of bumblebee nests. While the writer has no definite information on *G. mellonella* and *A. grisella* it seems possible that both species may be found occasionally in bumblebee nests.

The larva of another species of moth, *Aphomia sociella* L. has been reported as a pest of bumblebee nests in Europe by Hoffer (1882–83) and Sladen (1912). Forbes (1923) reported it as present in Novia Scotia and Massachusetts, having been introduced from Europe. Forbes definitely states that it is not found in nests of honeybees. Suire (1932) in a paper entitled, "Remarques sur la biologie des teignes des Ruches" lists *A. sociella* L., together with *G. mellonella* (L.) and *A. grisella* F., the latter designated by Suire as *Meliphora* (*Achroea*) *grisella* (F) based on the work of Meyrich in 1925. Suire says that the former "has little interest to us because it is habitually the pest of nests of *Bombus* and other wild honey-gatherers." Whether Suire actually implies that *A. sociella* may be found occasionally as a pest in honeybee combs is questionable but it is not unreasonable to suspect that it may be so found within the range of its distribution. According to Sladen (1912) it feeds upon the brood and probably everything else in the bumblebee's nest.

On the basis of the information given here, the combs or nests of bumblebees and honeybees definitely have at least three and possibly have four other pests in

common, some rarely. They are *Plodia interpunctella* (Hbn.), *Ephestia kuehniella* Zell., *Vitula edmandsii* Pack. and possibly *Aphomia sociella* L., *Galleria mellonella* (L.), *Achroia grisella* F. and *Ephestia cautella* (Walk.).

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# Whitewash to Control Potato Leafhopper on Citrus

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For the past several years injury to oranges of the nature of a rind spot on maturing fruit during the late fall and winter months has been of increasing importance in central California. This injury was believed to be caused by feeding punctures of a leafhopper, several species of which have been noted to overwinter in citrus orchards. In 1931, adults of *Empoasca fabae* Harris were collected among other species of leafhoppers prevalent on citrus at the time rind spot developed commercial significance. Injury was not of sufficient importance to be of concern again until the years 1936 to 1938, when field observations by the writers indicated *E. fabae* Harris to be the species responsible for the fruit spotting. In the fall of 1938, H. J. Quayle of the Citrus Experiment Station, Riverside, California, definitely established by cage experiments the fact that the rind spot was due to feeding punctures of this insect. This was apparent also in the field from the abundance of *Empoasca* feeding on the fruit.

During the summer of 1938 the writers found *Empoasca* breeding on cocklebur and sunflower, common weeds in central California. During the months of October and November of 1938 with the advent of cool weather and drying of host plants, adult *Empoasca* migrated into citrus groves. These overwintering adults congregate on exposed fruits where they may be found throughout the winter, with favorable weather. Navel oranges are most severely damaged by the earlier incursions of this pest, whereas the later ripening Valencia variety is marked mostly during the winter.

In attempting to find a suitable control practice two possibilities or methods were considered. The first was to reduce the population of hoppers by means of a contact insecticide. The second was to find a suitable repellent to keep the *Empoasca* away from treated groves. Obviously, a suitable repellent would prove the more satisfactory. Treating heavy foliaged citrus trees with a contact insecticide presented difficulties and was relatively expensive. Furthermore, even though a satisfactory kill could be obtained, there was the additional chance of subsequent reinfestation by migrating adult hoppers. However, both methods were investigated.

Pyrethrum, which is used against the grape leafhopper in central California was first tried as a liquid *Vapo-dust* atomized in oil on the treees. It was difficult to get a suitable coverage and the kill was unsatisfactory. Pyrethrum was also used as a dust at the rate of 1 pound per tree of a material containing 0.2 per cent pyrethrins. This treatment reduced spotting about 90 per cent during the first week following application, but the population of hoppers again increased. A 10 per cent nicotine dust afforded some reduction of hoppers, but not enough, and was expensive.

*Cyanogas* was tried at the rate of 40

pounds per acre, broadcast on the ground under the trees by a power blower. Although some hoppers were killed, little or no control was obtained. Heavier application might prove more effective.

The following materials were tried as repellents in the dust form: 325-mesh sulfur as yellow, also as black, gas; also as a mixture with pyrethrum; 12¾ per cent copper bordeaux; 22 per cent copper bordeaux; 10 per cent copper and 10 per cent zinc bordeaux; 11 per cent copper bordeaux with pyrethrum; *Vigrocide* a sulfide sulfur-zinc mixture; *Vigrocide* plus rotenone; *Repello*, a copper mixture; and hydrated lime. None of these materials proved satisfactory although some reduction in population of leafhoppers was obtained. This was more or less in proportion to the deposit of material.

The following materials were tried as repellents in the liquid spray form: copper bordeaux 5–7–50; a copper-pyrethrum mixture in one-half per cent oil; 2 gallons liquid lime-sulfur plus 4 pounds wettable sulfur to 100 gallons; 2 gallons liquid lime-sulfur plus 3 pounds zinc oxide to 100 gallons; a whitewash composed of lime, zinc sulfate and blood albumin; and tetramethyl thiuram disulfide (du Pont). So far as was determined, none of the following materials, copper, zinc, oil, pyrethrum rotenone or sulfur, indicated any repellent action. Tetramethyl thiuram disulfide may act as a repellent, since, used at the rate of 4 pounds per 100 gallons, it showed some promise with only a light white spray coating.

WHITEWASH.—Hydrated lime dust was tried because of the success reported by McDaniel (1937) in repelling this leafhopper from dahlias with this material as well as with talc and flour. However, the application of lime as a dust did not coat the trees white enough for satisfactory control and the coating did not persist long because of weathering. It was evident that something whiter and more permanent than a dust application of lime would be necessary to accomplish control on citrus. Therefore, a liquid whitewash with the same formula as that commonly used on citrus trees to prevent sunburn was tried and found to be very effective. Leafhoppers immediately left the whitewashed grove and did not return during the winter. An outside coating only, which facilitates treatment as well as minimizes the cost, is required. The formula first used was hydrated lime 150 pounds, zinc sulfate 25 pounds, blood albumin 12 ounces, in 300 gallons of water. Approximately two tanks per acre of average sized trees were applied at a total cost of $8.00 per acre. In addition to maintaining an orchard free from leafhoppers this spray application is of further value in mottle-leaf control and tree growth stimulation because of the zinc which it contains. In central California it is generally considered advisable to apply some zinc each season to citrus trees.

The first experiments with whitewash were made early in November 1938 and as the results were satisfactory commercial applications were commenced in the latter part of the same month and continued throughout December, January and February. Forty-three Valencia groves comprising 763 acres were treated with the above whitewash formula or variations of it during the past season. In every case hoppers almost entirely disappeared, immediately, from treated groves or portions of groves. There was no damage following the use of the recommended formula but in one case injury followed when dry lime-sulfur and oil were added to the whitewash. The mature fruit has been washed and cleaned satisfactorily. New growth and the setting of the new crop appears normal. Since lime may have some desiccating effect, the mature fruit may at times appear to be slightly softer than untreated fruit; however, no definite ill-effect has yet been established. At the present time the recommended formula is hydrated lime 100 pounds, zinc sulfate 25 pounds, blood albumin 12 ounces, in 300 gallons of water.

The effectiveness of this treatment was shown by the production records of a small Valencia grove which was whitewashed on November 20 using the above formula with 150 pounds of lime instead of 100 pounds. A part of the grove was untreated. The fruit was picked and packed commercially late in April. The untreated part showed a pack-out of 52 per cent first grade fruit and 30 per cent unmerchantable or by-product fruit. The treated part showed a pack-out of 72 per cent fancy grade fruit and 12 per cent by-product. Thus, the whitewashed plot showed a 37 per cent improvement over

the untreated in yield of first grade fruit.

SUMMARY.—Overwintering adult leafhoppers, *Empoasca fabae* Harris, cause fruit spotting on mature oranges in central California citrus areas. A repellent, which to date has been very satisfactory, is whitewash. The entire trees are given an outside coating of a spray containing 100 pounds of hydrated lime, 25 pounds of zinc sulfate and 12 ounces of blood albumin spreader in 300-gallons of water. The cost of this treatment is about $8.00 per acre. The inclusion of zinc is of additional benefit in mottle-leaf control and tree growth stimulation.

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# Rating Thoroughness of Application in Spraying Citrus Trees

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Extensive research on oil emulsions, miscible oils and other forms of oil spray has been carried on during the past fifty years. As a result, notable contributions to the knowledge of such sprays have been made and a vast amount of literature on the subject has come into existence. Although much emphasis has been placed upon thoroughness of spray application, research and contributions on this feature of insect control have been meager. The explanation for the great difference in the amount of research done on spray materials as compared with that done on spray application may be readily understood. The qualities of oil spray materials are expressible in terms of viscosity, volatility, unsulfonatable oil, emulsifying substances, oil deposit, killing effectiveness, etc., all of which are amenable to formal experimentation and to quantitative or qualitative measurement. Spray application, on the other hand, pertains to technique, skill, experience, conscientiousness, physical and mental capabilities and similar human factors which cannot be specifically measured or evaluated. The good sprayman, like the good mason, sculptor, surgeon or other artisan, is gifted with particular qualities of perception, learning ability, coordination, physical endurance, knowledge and integrity which are peculiarly correlated with proficiency in the particular art.

The experienced spray operator or spray inspector can readily single out a sprayman who does poor work merely by watching him spray a few trees. Such a sprayman may miss areas on the exterior surface of the tree or he may cover the exterior surface quite thoroughly, but because of improper manipulation of the gun and the torrent of spray, the branches and foliage lying deeper in the tree may be very poorly covered. It is fair to say that the majority of experienced spraymen are proficient, but it is not reasonable to believe that they have the same degree of proficiency. If a method were available for determining spraying proficiency on a mathematical basis, similar to that by which the efficacy of insecticide treatments is determined, investigations probably would reveal that the range in proficiency among spraymen is as great as the range in killing values of the standard insecticides. This conclusion was constantly forced upon the attention of the writer during the several years that he studied the problem of spraying with oil for the control of the black scale, *Saissetia oleae* (Bern.).

METHODS OF RATING THOROUGHNESS.—Three methods were employed in evaluating thoroughness of application and the proficiency of spraymen. The first was based upon the examination of clusters of leaves, fruits and twigs immediately after trees had been sprayed; the second was based upon the examina-

tion of leaves three or four weeks after spraying, to determine the number and distribution of the insects that survived; the third was based upon unit counts made in June, following the spraying in August of the preceding year, to determine the number of insects present on rows of trees treated by different spraymen.

The cluster method is described as follows: as soon as the sprayman completes the spraying of a tree, a cluster of smaller branches is grasped by the hand. The cluster is as large as can be conveniently grasped and is located a little below shoulder height. The position of the hand is eight to ten inches from the tips of the branches. The cluster is moved laterally and downward while it is viewed sharply with the object of detecting any leaves or portions of leaves that are not completely covered by a film of spray or oil. This phase of the examination is concerned mostly with the coverage of the outer surface of the leaves that form the exterior wall of foliage. The cluster is then turned upward with the object of bringing into view the lower surface of the leaves, the bark of the twigs and the leaves lying deeper in the tree. This phase of the examination is particularly important inasmuch as the parts mentioned are protected from the spray by the outside wall of foliage and are more likely to be imperfectly covered. Some experience or practice is necessary in order that one may quickly and accurately detect uncovered parts of leaves and bark. Dry, uncovered areas of brown, rough bark can be readily distinguished from the surface that is wetted by the spray. Uncovered areas on green bark and the lower surface of leaves are rather difficult to distinguish. They are somewhat dull and without gloss whereas the oil-covered surface has a shiny appearance.

Where the application is somewhat below average in thoroughness, the examinations will reveal occasional leaves that have received no spray on one surface, and a larger number that are adequately covered on the distal portions but have uncovered areas at the basal portions. Where the application is especially thorough, the uncovered areas may be represented by an occasional leaf having a complete film of oil except on a small portion which did not receive sufficient spray to produce a film. This portion may be covered by droplets of spray. The areas between the droplets are dry. Some of these inter-droplet areas may be no larger than the area of the head of a pin. However, as many as 15 or 20 black scale insects two or three months old can be placed side by side on the head of a pin. In spraying heavily infested groves, therefore, small inter-droplet areas, if they are numerous, may account for unsatisfactory control. While it is not practicable to inspect leaves with sufficient sharpness to detect individually the smaller uncovered areas, one can readily detect a portion of a leaf or fruit that is covered by a droplet coverage as distinguished from a film coverage.

The examination of a cluster is completed in approximately fifteen seconds. No attempt is made to inspect the leaves individually. On the contrary, the examination is rather superficial. If no uncovered leaves or portions are observed as the cluster is manipulated by the one hand in the manner above described, the free hand is brought into use to open the cluster somewhat with the object of bringing into view a larger number of leaves. Twenty clusters, selected at random and evenly distributed around the tree are examined. In the studies that have been made, four trees were examined for each spray crew, two trees for each sprayman. The coverage on the fruit was checked particularly in the spraying of lemons infested with red scale.

COVERAGE RATINGS OF SPRAY CREWS.—The results of studies of 22 spray crews are given in table 1. While the studies were made in 1931 and 1932, examinations made during the spray season of 1938 showed about the same degree of thoroughness as that which prevailed in 1931 and 1932. The data are believed to be applicable to present-day spraying. Table 1 gives the number of clusters, out of 20 examined per tree, that showed no uncovered areas and that were rated, therefore, as completely covered.

In analyzing the data, we may first consider the fact that they do not tell the whole story. Spray crew No. 4 showed many uncovered leaves or portions of leaves in every cluster examined. This crew was working in a grove that was lightly infested with black scale, and the application was light intentionally. Pos-

sibly 20 per cent of the total surface area of the leaves, bark and fruit was uncovered. The rating would probably have been the same had 5 per cent of the total area been uncovered. The ratings of the various spray crews, therefore, are but roughly comparative.

Not one spray crew achieved 100 per cent coverage, that is to say, complete coverage. The nearest approach to this was attained by No. 14 but even in this case 40 per cent of the clusters showed uncovered areas. While the uncovered areas may have constituted but a small fraction of the total surface of the leaves, fruit and bark, many insects would have escaped a coverage of oil if the surfaces had been heavily infested.

The ratings cover the work of 44 spraymen. As indicated in the percentage columns of the table 16 of the spraymen attained complete coverage of 0 to 10 per cent of the clusters. Only 6 spraymen attained complete coverage above 50 per cent. The best coverage was attained by sprayman 1 of spray crew No. 19, and his ratings show that but 67.5 per cent of the clusters were completely covered.

The averages at the foot of table 1 show that approximately 23 per cent of all the clusters examined were completely covered. The very close agreement in the averages of the various columns must be regarded as exceptional, and probably does not correctly reflect the reliability of the data.

The ratings for spray crew No. 12 indicate that the spraymen were poorly matched as regards their proficiency in application. Not one cluster on the trees treated by sprayman 1 showed complete coverage while 62.5 per cent of the clusters treated by sprayman 2 showed complete coverage. This indication is substantiated by unit counts, made the following June, given in table 4. A similar condition appears to have existed in the case of spray crews 5, 6 and 18.

**Table 1.—Data on spray application, showing the number of clusters, out of 20 examined per tree, that were completely covered.**

| | | | Sprayman 1 | | | Sprayman 2 | | |
|---|---|---|---|---|---|---|---|---|
| Spray crew | Date | Kind of Trees | Tree 1 Clusters completely covered | Tree 2 Clusters completely covered | Per cent of clusters completely covered | Tree 1 Clusters completely covered | Tree 2 Clusters completely covered | Per cent of clusters completely covered |
| 1 | Aug. 1931 | Oranges | 2 | 0 | 5 | 3 | 4 | 17.5 |
| 2 | Aug. 1931 | Oranges | 4 | 9 | 32.5 | 6 | 4 | 25 |
| 3 | Aug. 1931 | Oranges | 6 | 2 | 20 | 0 | 1 | 2.5 |
| 4 | Aug. 1931 | Oranges | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | Aug. 1931 | Oranges | 9 | 13 | 55 | 1 | 2 | 7.5 |
| 6 | Aug. 1931 | Oranges | 0 | 0 | 0 | 5 | 6 | 27.5 |
| 7 | Aug. 1931 | Oranges | 6 | 2 | 20 | 6 | 8 | 35 |
| 8 | Oct. 1931 | Lemons | 0 | 0 | 0 | 2 | 0 | 5 |
| 9 | Oct. 1931 | Lemons | 3 | 5 | 20 | 0 | 4 | 10 |
| 10 | Oct. 1931 | Lemons | 3 | 2 | 12.5 | 2 | 1 | 7.5 |
| 11 | Oct. 1931 | Oranges | 2 | 6 | 20 | 0 | 0 | 0 |
| 12 | Sept. 1932 | Oranges | 0 | 0 | 0 | 15 | 10 | 62.5 |
| 13 | Sept. 1932 | Oranges | 2 | 4 | 15 | 1 | 4 | 12.5 |
| 14 | Sept. 1932 | Oranges | 13 | 10 | 57.5 | 14 | 11 | 62.5 |
| 15 | Sept. 1932 | Oranges | 2 | 0 | 5 | 0 | 0 | 0 |
| 16 | Sept. 1932 | Lemons | 10 | 10 | 50 | 14 | 9 | 57.5 |
| 17 | Sept. 1932 | Oranges | 7 | 5 | 30 | 4 | 2 | 15 |
| 18 | Sept. 1932 | Lemons | 6 | 9 | 37.5 | 2 | 0 | 5 |
| 19 | Sept. 1932 | Lemons | 12 | 15 | 67.5 | 10 | 10 | 50 |
| 20 | Sept. 1932 | Lemons | 8 | 0 | 20 | 2 | 1 | 7.5 |
| 21 | Sept. 1932 | Oranges | 4 | 2 | 15 | 7 | 4 | 27.5 |
| 22 | Sept. 1932 | Oranges | 9 | 8 | 42.5 | 12 | 8 | 50 |
| | | Average | 4.91 | 4.64 | 23.9 | 4.82 | 4.04 | 22.2 |

THOROUGHNESS, INDICATED BY SURVIVING INSECTS.—Two methods have been employed in determining the effectiveness of sprays in the control of black and citricola scales, the one known as the leaf count and the other known as the unit count. Each method yields data which reflect the part played by thoroughness of application as distinguished by that played by the killing potency of the insecticide. Where the kill throughout the tree is good generally but live insects are found in disproportionately large numbers on individual leaves or leaf clusters, one is warranted in believing the particular leaves or clusters were missed or were incompletely covered during the spray application. Likewise, where mature insects are found in disproportionately large numbers on the twigs and smaller

branches on limited portions of the tree, one may assume that the particular portions were incompletely covered when the spray was applied the preceding autumn.

The leaf counts upon which the data given in table 2 are based, were made in the manner described as follows: Three

Table 2.—Leaf counts of black scale.

| Tree | No. Leaves Examined | No. Infested Leaves | No. Insects Examined | No Insects Alive | Per cent Alive |
|---|---|---|---|---|---|
| 1 | 50 | 4 | 1371 | 18 | 1.31 |
| 2 | 50 | 0 | 906 | 0 | 0.00 |
| 3 | 50 | 1 | 540 | 1 | 0.19 |
| 4 | 50 | 2 | 633 | 3 | 0.47 |
| 5 | 50 | 3 | 508 | 3 | 0.59 |
| 6 | 50 | 9 | 1107 | 35 | 3.16 |
| 7 | 50 | 1 | 720 | 1 | 0.14 |
| 8 | 50 | 2 | 859 | 5 | 0.58 |
| 9 | 50 | 2 | 435 | 3 | 0.69 |
| 10 | 50 | 0 | 385 | 0 | 0.00 |
| Total | 500 | 24 | 7464 | 69 | 0.92 |

weeks after spraying, 50 leaves were picked at random from each of ten trees. The leaves were taken a foot or so inside the periphery of the tree where they were partly sheltered by the more exterior leaves. That is, there location was such that they were not directly exposed to the spray stream. On the other hand, they were not completely hidden by the outside wall of foliage nor were they taken deep inside the tree where the spray coverage would have been more incomplete. They were taken about shoulder height. This is the region where the best coverage is attained. The poorest coverage invariably occurs at the upper portions and at the skirts of the tree. With the aid of a magnifying lens, the upper surface of each leaf was examined and a record was made of the total number of insects and of the number alive.

The data in table 2 require careful analysis. With tree 1 a total of 1,371 insects were counted. Of this number 18 were alive. The live insects occurred on four leaves. On the other 46 leaves the kill was complete. At once there arises the question: Does the survival of the 18 insects indicate that the particular oil was low in insecticidal value or does it indicate that the four leaves were incompletely covered by the spray application? Although it is not shown in the table, 13 of the live insects occurred on a single leaf.

With tree 6 a total of 1,107 insects were counted and 35 were alive. The 35 live insects were distributed on 9 leaves. Thirteen occurred on a single leaf and the total number of insects on this leaf was 56.

From tree 8 a total of 859 insects were counted and 5 were alive. Four of the 5 live insects occurred on one leaf. The counts of trees 2 and 10 show a one hundred per cent kill. However, there is not much doubt but that live insects would have been found had a larger number of leaves been examined.

Altogether 500 leaves were examined and 7,464 insects were counted. Of the 500 leaves, 24 bore live insects. Of the 69 live insects found, 51 occurred on 8 leaves. In most instances where live insects were found in numbers, they occurred on a limited portion of the leaf. Evidently that particular portion was missed or was incompletely covered when the spray was applied. It appears that incomplete coverage is the logical explanation for most of the live insects. If the oil had been too light or if it had been used at too low a concentration, and the coverage had been complete on all the leaves, live insects would probably have occurred evenly distributed on a large number of leaves. In this case the counts would have shown approximately the same percentage of insects alive on the different trees.

Poor Application Indicated by Leaf Counts.—Leaf counts of the type discussed were made in a large number of groves and encompassed the work of many spray crews. The data given in table 2 are representative of results obtained where an especially thorough application was made on heavily infested orange trees. In these extended studies it was found that where the application was about average or was below average in thoroughness, the number of missed leaves was so large that the problem of evaluating the efficacy of a particular insecticide became very difficult. With the object of eliminating the factor of thoroughness of application, where the purpose of the counting was to evaluate the efficacy of the insecticide, the practice of discarding missed leaves was adopted. That is, no record was made of a leaf if live insects occurred in numbers on a limited portion or if all the insects on the leaf or nearly all were alive.

In groves where the application had been poor, the inefficacy of the application so overshadowed the efficacy of the insecticide that it was virtually impossible

**Table 3.—Leaf counts of black scale, made in a poorly sprayed grove; 20 leaves examined on each tree.**

| | | Leaf Number | | | | | | | | | | | | | | | | | | | | Percentage Alive | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tree | Insects | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | Total | "Starred" included | "Starred" not included |
| 1 | counted | 12 | 36 | 17 | 12 | 24 | 16 | 8 | 17 | 45 | 26 | 16 | 9 | 30 | 11 | 9 | 2 | 9 | 5 | 3 | 5 | 312 | 0.00 | 0.00 |
| | alive | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| 2 | counted | 4 | 11 | 3 | 4 | 4 | 5 | 10 | 4 | 9 | 3 | 3 | 14 | 3 | 3 | 4 | 3 | 40 | 20 | 25 | 36 | 208 | 8.65 | 2.88 |
| | alive | 0 | 0 | 0 | 0 | 0 | 3* | 6 | 0 | 7* | 0 | 0 | 1* | 0 | 0 | 0 | 0 | 0 | 0 | 1* | 0 | 18 | | |
| 3 | counted | 9 | 10 | 10 | 16 | 28 | 3 | 16 | 6 | 5 | 5 | 6 | 3 | 3 | 5 | 28 | 21 | 6 | 14 | 6 | 17 | 217 | 2.76 | 1.38 |
| | alive | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3* | 0 | 0 | 0 | 0 | 0 | 6 | | |
| 4 | counted | 3 | 2 | 18 | 12 | 2 | 6 | 7 | 7 | 5 | 7 | 18 | 18 | 2 | 20 | 4 | 7 | 5 | 16 | 7 | 6 | 172 | 0.00 | 0.00 |
| | alive | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| 5 | counted | 6 | 3 | 2 | 12 | 15 | 3 | 4 | 3 | 5 | 4 | 3 | 6 | 6 | 11 | 5 | 11 | 4 | 3 | 12 | 3 | 121 | 0.00 | 0.00 |
| | alive | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| 6 | counted | 4 | 4 | 6 | 7 | 26 | 12 | 15 | 16 | 10 | 5 | 6 | 6 | 8 | 4 | 3 | 3 | 34 | 23 | 13 | 6 | 211 | 20.28 | 9.00 |
| | alive | 0 | 0 | 0 | 0 | 24* | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 18 | 0 | 0 | 43 | | |
| 7 | counted | 3 | 17 | 3 | 6 | 8 | 15 | 24 | 8 | 17 | 26 | 24 | 4 | 5 | 3 | 9 | 5 | 10 | 26 | 4 | 3 | 220 | 0.00 | 0.00 |
| | alive | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| 8 | counted | 9 | 8 | 6 | 5 | 6 | 6 | 4 | 4 | 8 | 3 | 7 | 4 | 15 | 6 | 6 | 3 | 5 | 7 | 10 | 8 | 130 | 11.54 | 0.00 |
| | alive | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1* | 0 | 1* | 6* | 0 | 0 | 0 | 0 | 0 | 0 | 7* | 15 | | |
| 9 | counted | 9 | 10 | 3 | 14 | 10 | 7 | 11 | 8 | 10 | 4 | 9 | 6 | 7 | 4 | 5 | 8 | 4 | 6 | 6 | 5 | 146 | 0.00 | 0.00 |
| | alive | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| 10 | counted | 3 | 4 | 3 | 3 | 8 | 3 | 3 | 4 | 3 | 5 | 4 | 6 | 3 | 3 | 4 | 8 | 3 | 6 | 3 | 4 | 83 | 4.82 | 1.20 |
| | alive | 0 | 0 | 1* | 0 | 1* | 0 | 0 | 1 | 0 | 1* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| | Total insects counted | | | | | | | | | | | | | | | | | | | | | 1820 | 4.73 | 1.65 |
| | Total insects alive | | | | | | | | | | | | | | | | | | | | | 86 | | |

to evaluate the efficacy of the insecticide with any fair degree of accuracy. An example of counts involving this condition is given in table 3. In this grove, 20 leaves to the tree were examined. Leaves considered to have been missed were not discarded but instead the insects were counted and the entry was marked by a star. When but one live insect occurred on a leaf, the insect was regarded as missed providing it was some distance from dead insects. If it was almost contiguous to dead insects, it was considered to have been covered by the spray.

Referring to table 3, it will be noted that two sets of "percentage alive" computations are given. The one shows the percentage of all live insects, both starred and unstarred; the other does not include the starred insects or those considered to have been missed. The shortcoming of this method of attempting to distinguish and evaluate separately the efficacy of the insecticide and the efficacy of the application is obvious. As a case in point, 43 live insects were counted on tree 6. Twenty-four of these were considered to have been missed, and were starred. Eighteen live insects occurred on leaf 18. This leaf bore a total of 23 insects, and all of these insects were considered to have been covered. They were so considered because the live insects were in close proximity to dead insects. However, proximity to the dead insects is by no means conclusive evidence that the live insects were covered by the film or drops of spray. The entire leaf may have been covered by fine droplets of spray. Each of the insects killed may have been covered by a droplet while the surviving insects may have been on inter-droplet areas and, therefore, untouched by spray.

The spray applied in this grove was the same as that applied in the grove from which were derived the data given in table 2. Obviously the difference in the percentage of insects surviving in the two groves is due to differences in application.

THOROUGHNESS INDICATED BY UNIT COUNTS.—The unit counts upon which the data of tables 4 and 5 are based were made in the manner described as follows: about the middle of June, when the black scale insects were full grown and established upon the bark of the twigs and smaller branches, counts were made of the insects on 20 units selected at random on a desired number of trees. A unit consisted of the terminal portion of a branch and the twigs borne thereon, the terminal

portion being about 10 inches in length. The units examined were a little below shoulder height on the tree. The unit bears, on the average, about 20 leaves. Most of the insects that survive the spray, and thereafter survive their winter migration from the leaves to the bark, will be found on the twigs and terminal portions of the branches which constitute the units.

Table 4 gives unit counts that were made in the grove sprayed by spray crew numbered as on the odd-numbered trees. Of the 483 insects found on the 30 trees, 319 occurred on the even-numbered trees and 164 on the odd-numbered. This indicates that sprayman 1 missed twice as many insects and, therefore, did only half as good a job as was done by the second sprayman.

The right hand column of figures gives the number of units on which insects occurred. This shows consistently a larger number of insect-bearing units on the

**Table 4.—Unit counts of black scale, showing the number of insects on every unit examined on thirty trees across the end of a 10-acre orange grove.**

| | Unit | | | | | | | | | | | | | | | | | | | | Total Number of Insects | Average No. of Insects per Unit | Number of Units Bearng Insects |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tree | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | | | |
| | Number of insects | | | | | | | | | | | | | | | | | | | | | | |
| 1 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 2 | 0 | 11 | .55 | 4 |
| 2 | 0 | 0 | 1 | 0 | 0 | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 12 | .60 | 4 |
| 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 7 | .35 | 2 |
| 4 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 6 | 1 | 0 | 0 | 1 | 0 | 12 | .60 | 5 |
| 5 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | .10 | 2 |
| 6 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 8 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 1 | 15 | .75 | 4 |
| 7 | 4 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 6 | .30 | 3 |
| 8 | 0 | 1 | 0 | 0 | 0 | 2 | 0 | 0 | 5 | 0 | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 11 | .55 | 5 |
| 9 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 0 | 7 | .35 | 4 |
| 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 0 | 1 | 14 | .70 | 5 |
| 11 | 0 | 0 | 0 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 8 | .40 | 4 |
| 12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 8 | 0 | 0 | 0 | 0 | 4 | 1 | 0 | 3 | 12 | 0 | 0 | 29 | 1.45 | 6 |
| 13 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 2 | 0 | 0 | 1 | 1 | 0 | 0 | 2 | 0 | 0 | 1 | 0 | 0 | 8 | .40 | 6 |
| 14 | 0 | 0 | 3 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 3 | 2 | 1 | 1 | 0 | 0 | 0 | 0 | 12 | .60 | 7 |
| 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 3 | .15 | 2 |
| 16 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 2 | 0 | 0 | 0 | 0 | 2 | 9 | .45 | 5 |
| 17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 1 | 5 | .25 | 4 |
| 18 | 0 | 0 | 3 | 0 | 6 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 11 | .55 | 4 |
| 19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 2 | 0 | 1 | 0 | 0 | 1 | 0 | 6 | .30 | 5 |
| 20 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 11 | 0 | 0 | 0 | 2 | 15 | 2 | 0 | 0 | 0 | 0 | 32 | 1.55 | 6 |
| 21 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 4 | 0 | 0 | 9 | 0 | 0 | 0 | 0 | 14 | .70 | 3 |
| 22 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 10 | 0 | 3 | 0 | 4 | 0 | 1 | 0 | 0 | 0 | 21 | 1.05 | 7 |
| 23 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 8 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 4 | 0 | 0 | 0 | 17 | .85 | 6 |
| 24 | 0 | 0 | 0 | 2 | 0 | 1 | 9 | 0 | 0 | 1 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 1 | 20 | 1.00 | 9 |
| 25 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 4 | 0 | 0 | 2 | 0 | 0 | 1 | 1 | 5 | 16 | .80 | 7 |
| 26 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 1 | 1 | 13 | 0 | 2 | 0 | 0 | 1 | 0 | 1 | 2 | 1 | 23 | 1.25 | 9 |
| 27 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 5 | 1 | 0 | 2 | 1 | 0 | 0 | 0 | 11 | 0 | 0 | 0 | 0 | 23 | 1.15 | 7 |
| 28 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 12 | 0 | 1 | 0 | 1 | 0 | 2 | 1 | 19 | 1 | 1 | 42 | 2.10 | 11 |
| 29 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 17 | 0 | 0 | 0 | 2 | 3 | 1 | 0 | 0 | 2 | 0 | 3 | 0 | 31 | 1.55 | 9 |
| 30 | 1 | 3 | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 1 | 1 | 4 | 3 | 29 | 0 | 0 | 2 | 2 | 1 | 4 | 54 | 2.70 | 13 |
| Total | 8 | 7 | 12 | 8 | 20 | 15 | 15 | 36 | 32 | 43 | 37 | 15 | 18 | 51 | 36 | 35 | 16 | 47 | 15 | 17 | 483 | | 168 |

12, cited in table 1. The results of the cluster examinations, shown in table 1, indicated that sprayman 2 did much better work than did sprayman 1. The unit counts were made across the end of the 10-acre grove. The 30 trees examined represent the 30 rows of trees comprising the grove. The odd-numbered trees represent the rows sprayed by sprayman 2, the even-numbered represent those sprayed by sprayman 1.

A number of facts pertaining to thoroughness of application are indicated by the data of table 4. A study of the column of figures which gives the total number of insects on the 20 units of each tree and the column which gives the average number of insects per unit, shows, consistently about twice as many insects on the even-numbered trees than on the odd-numbered. Of 168 such units, 100 occurred on the even-numbered trees, sprayed by sprayman 1.

Further study of table 4 shows that in the case of trees, 2, 3, 4, 5, 6, 15, 18, 21, 29 and 30, fifty per cent or more of the insects found on the different trees occurred on one unit. In the case of every one of the thirty trees, at least fifty per cent of the insects occurred on two units. The disproportionately large number of insects that occurred on an occasional unit can be accounted for by the assumption that at least one leaf on such unit was missed or was incompletely covered when the spray was applied in September of the preceding year.

The western portion of the grove, repre-

sented approximately by trees 19 to 30, inclusive, was more heavily infested than the remainder. The owner stated that this condition had existed for several years. The spraymen failed to increase the degree of thoroughness of their application on this portion of the grove in order to offset the heavier degree of infestation.

The results of unit counts encompassing every tree in a ten-acre orange grove are shown in table 5. This grove had been used for making a series of tests with various oil sprays. Sixteen tests are represented. Test 1 involved the use of but one row of trees, namely, row 1. This row was heavily infested when the spray was applied, owing to the fact that it had received no treatment for scale the preceding year. Each of the other tests, 2 to 16, inclusive, included two rows of trees. Row 1 was sprayed jointly by sprayman 1 and sprayman 2. With the remainder of the grove, the even-numbered rows were sprayed by sprayman 1, the odd-numbered by sprayman 2. Tree 3 of every row received no treatment.

No cluster ratings on thoroughness of application were made when the spraying was done. As far as was casually observed the two spraymen appeared to be about equal in proficiency. However, when the counts made the following June were tabulated, as shown in table 5, the fact became apparent that sprayman 1 consistently did a much better job than did sprayman 2. The unit counts shown for rows 2 and 3 may be disregarded because of the fact that row 2, being adjacent to the previously unsprayed row 1, was without doubt more heavily infested than was row 3. Excepting test 2, comprising rows 2 and 3, and test 1 above mentioned, the data of table 5 show that there was a notably larger number of insects on the odd-numbered than on the even-numbered rows. In seven of the tests, the rows treated by sprayman 2 showed more than twice as many insects as did the rows treated by sprayman 1.

SUMMARY.—In experiments with various oil sprays in the control of the black scale, *Saissetia oleae* (Bern.) the range in degree of thoroughness of spray application was found to be as great as the range in killing values among the spray compositions tested. Three methods were employed in evaluating thoroughness of application. The first involved the examination of clusters of leaves, fruits and twigs immediately after spraying, to determine whether or not uncovered parts were present; the second the examination of leaves three or four weeks after spraying, to determine the number and distribution of insects that survived the spray treatment; the third involved the making of unit counts in June following the spraying in August of the preceding year, to determine the number of insects present in rows of trees treated by different spraymen. Ratings on the work of 44 spraymen are given in detail in 5 tables. Marked differences in proficiency of spray application are shown by the tabulated counts.

**Table 5.—Unit counts of black scale, showing the average number of insects per unit for every tree in a 10-acre orange grove.**

| | Unit 1 | | Unit 2 | | Unit 3 | | Unit 4 | | Unit 5 | | Unit 6 | | Unit 7 | | Unit 8 | | Unit 9 | | Unit 10 | | Unit 11 | | Unit 12 | | Unit 13 | | Unit 14 | | Unit 15 | | Unit 16 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Row | 1 | | 2 | | 3 | | 4 | | 5 | | 6 | | 7 | | 8 | | 9 | | 10 | | 11 | | 12 | | 13 | | 14 | | 15 | | 16 | | Average |
| East | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | .50 | .00 | .00 | .00 | .10 | .00 | .00 | .00 | .00 | .10 | .10 | .00 | .10 | .00 | .10 | .00 | .10 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .15 | .00 | 20 | .07 |
| 2 | .65 | .20 | .00 | .10 | .00 | .00 | .00 | .10 | 20 | .25 | 20 | .70 | .10 | .40 | .25 | .20 | .10 | .25 | .05 | .40 | .00 | 1.10 | .10 | .20 | .10 | .00 | .10 | .25 | .15 | .00 | .00 | | .23 |
| 3 | 6.40 | 6.70 | 6.70 | 6.10 | 7.20 | 5.80 | 7.20 | 13.10 | 5.90 | 6.00 | 6.60 | 5.70 | 5.80 | 5.10 | 20 | 7.20 | 5.80 | 5.80 | 5.80 | 5.80 | 6.70 | 6.10 | 5.40 | 5.10 | 6.40 | 6.90 | 5.80 | 5.40 | 5.80 | 2.40 | 20 | 6.00 |
| 4 | 20 | .40 | .20 | .10 | .40 | .10 | .20 | .10 | .20 | .20 | .25 | .10 | 20 | .00 | .20 | .15 | .70 | 20 | .25 | .10 | .05 | .10 | .10 | .10 | .10 | .00 | .10 | .05 | .00 | .10 | .05 | .10 | .19 |
| 5 | .15 | .20 | .20 | .00 | .20 | .20 | .25 | .10 | .20 | .15 | .05 | .10 | .20 | .00 | .20 | .10 | .25 | .20 | .10 | .40 | .10 | .05 | .15 | .10 | .05 | .00 | .00 | .10 | 20 | .05 | .00 | .10 | .08 |
| 6 | .70 | .00 | .00 | .10 | .20 | .00 | .10 | .00 | .05 | .70 | .20 | .05 | .05 | .15 | .15 | .10 | .10 | .20 | .40 | .00 | .25 | .05 | .05 | 20 | .05 | .10 | .10 | .00 | .00 | .10 | .10 | .00 | .19 |
| 7 | 1.20 | .10 | 20 | .00 | .40 | .15 | 20 | .05 | .40 | .00 | .10 | .00 | .40 | .00 | .20 | .10 | .50 | .25 | .20 | .10 | .20 | .15 | .05 | .00 | .00 | .00 | .20 | .00 | .10 | .00 | .00 | .00 | .20 |
| 8 | .20 | .10 | .40 | .20 | .20 | .05 | 20 | .05 | .05 | .50 | .15 | .20 | .20 | .20 | .20 | .10 | .00 | .20 | .75 | .20 | .00 | .10 | .10 | .00 | .05 | .00 | .05 | .05 | .05 | .00 | 20 | .05 | .24 |
| 9 | 20 | .05 | 1.60 | .40 | .60 | .40 | .70 | .10 | .20 | .25 | 1.00 | .00 | 1.00 | 20 | .20 | .05 | .25 | .00 | .20 | .25 | .05 | .00 | .20 | .10 | .25 | .00 | .10 | .20 | .15 | .15 | .05 | .24 |
| 10 | 2.10 | .20 | .40 | .20 | .40 | .10 | .25 | .00 | .05 | .00 | .70 | .15 | .10 | .00 | .00 | .05 | .25 | .10 | .00 | .00 | .00 | .25 | .10 | .10 | .20 | .00 | .20 | .10 | .00 | .00 | .05 | 20 | .27 |
| 11 | 2.10 | .05 | 1.20 | .10 | .20 | .15 | .70 | .05 | .20 | .25 | 20 | .00 | .10 | .00 | .15 | .00 | .20 | .25 | .25 | .15 | .20 | .00 | 20 | .05 | .05 | .00 | .15 | .00 | .05 | .00 | .15 | .25 | .23 |
| 12 | 2.60 | .20 | .20 | .00 | .40 | .10 | .40 | .00 | .70 | .50 | .20 | .10 | .15 | .25 | 20 | .00 | .20 | .20 | .25 | .20 | .15 | .10 | .15 | .00 | .05 | .00 | .10 | .00 | .10 | .20 | .45 | .25 | .26 |
| 13 | 1.10 | .70 | 2.10 | .00 | .40 | .00 | .50 | .00 | .20 | .20 | .10 | .40 | .05 | .25 | .00 | .10 | .70 | .05 | .15 | .10 | .10 | .05 | .00 | .25 | .00 | .20 | .00 | .20 | .05 | .20 | .20 | .20 | .20 |
| 14 | 2.60 | 1.20 | 1.50 | .00 | .20 | .10 | .20 | .25 | .20 | 2.05 | 2.40 | .25 | .20 | .00 | .00 | .10 | .20 | .20 | .40 | .00 | .20 | .05 | .20 | 20 | .00 | .00 | .10 | .15 | .15 | .00 | .05 | .01 |
| 15 | 2.40 | .75 | .75 | .00 | 20 | .05 | .60 | 20 | .20 | 1.50 | .25 | .20 | .50 | .05 | .50 | .00 | .25 | .20 | .20 | .05 | .45 | .10 | .00 | .05 | .50 | .05 | .05 | .40 | .25 | .15 | .15 | .05 | .02 |
| 16 | 20 | 2.05 | .20 | .00 | .20 | .10 | .40 | .00 | .05 | 1.60 | 2.25 | .25 | .25 | .40 | 20 | .00 | .20 | .20 | .20 | .05 | .15 | .25 | .15 | .00 | .20 | .15 | .20 | .15 | .20 | .05 | .15 | .05 | .01 |
| 17 | 2.70 | 1.20 | 1.40 | .10 | .20 | 20 | .75 | .05 | .05 | .25 | .40 | .20 | .10 | .10 | .05 | .15 | .20 | .40 | 20 | .20 | .25 | .10 | .00 | .10 | .20 | .00 | .10 | .15 | .20 | .05 | .40 | .05 | .04 |
| 18 | 2.00 | 1.70 | .40 | .15 | .25 | .00 | 1.00 | .15 | .05 | .05 | .25 | .00 | .20 | .20 | .20 | 1.15 | .20 | .70 | .20 | .20 | .10 | .15 | 20 | .00 | .10 | .25 | .25 | .00 | .40 | .05 | .40 | .05 | .02 |
| 19 | 2.00 | 2.40 | .20 | .20 | .20 | .25 | .40 | .70 | .10 | .20 | .40 | .15 | .20 | .20 | 2.20 | .20 | 20 | .40 | .20 | .05 | .40 | .10 | .00 | .00 | .15 | .10 | .00 | .20 | .40 | .05 | .25 | .05 | .00 |
| 20 | 1.40 | 1.40 | .40 | .25 | .20 | .00 | .40 | .05 | .20 | .05 | .40 | .10 | .40 | .15 | .25 | .00 | .40 | .40 | .10 | .05 | 20 | .00 | 20 | .00 | .20 | .00 | .05 | .05 | .15 | .20 | .10 | .05 | .21 |
| 21 | 20 | .60 | 1.60 | .40 | .20 | .05 | .20 | .10 | .05 | .00 | .25 | .15 | .00 | .00 | .15 | .10 | .25 | .00 | 1.05 | .40 | .05 | .15 | .05 | .00 | 20 | .05 | .20 | .00 | 20 | .05 | .10 | .05 | .02 |
| 22 | 1.70 | 1.20 | 20 | 1.40 | 1.25 | .20 | .25 | .05 | .20 | .05 | 5.00 | .25 | .40 | .10 | 1.40 | .25 | .25 | .40 | 20 | .25 | .15 | .05 | .40 | .25 | .10 | .00 | .10 | .05 | 20 | .10 | .20 | .05 | .07 |
| 23 | 2.10 | 6.15 | .40 | 2.10 | .40 | 1.05 | 1.90 | 1.20 | .40 | .05 | .75 | .05 | .40 | .05 | .25 | 1.00 | 1.25 | .40 | 1.15 | .75 | .25 | .40 | .25 | .20 | .40 | .15 | .10 | .10 | .40 | .10 | .05 | .05 | .03 |
| 24 | 2.00 | 1.05 | .25 | .00 | .75 | .25 | 1.05 | .20 | .20 | .05 | 1.20 | 20 | .40 | .10 | .45 | .00 | 1.05 | .20 | 1.05 | .05 | .20 | .10 | 20 | .10 | .45 | .05 | .25 | .05 | .05 | .20 | .10 | .40 | .02 |
| Aver-age | 2.07 | .96 | .79 | .31 | .45 | .18 | .40 | .18 | .19 | .05 | .05 | .19 | .20 | .09 | .44 | .20 | .42 | .07 | .07 | .18 | .16 | .10 | .10 | .09 | .21 | .04 | .12 | .10 | .09 | .18 | .07 | | .07* |

# Toxicants and Solids Added to Spray Oil in Control of California Red Scale[1]

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The addition of toxicants to citrus spray oil used in the control of the California red scale, *Aonidiella aurantii* (Mask.), has attracted the attention of an ever increasing number of investigators during the last decade. Until comparatively recent years, however, no promising results had been obtained along this line of investigation. Smith (1932a), after experimenting for a period of years with various substances added to highly refined petroleum spray oils, stated that the attempt to increase the effectiveness of the oils by the use of the toxicants available at that time, had been unsuccessful. Boyce *et al.* (1939) report the results of laboratory tests in which the addition of one per cent dinitro-o-cyclohexylphenol to spray oil increased the effectiveness of the oil against the red scale and state that this is the first quantitative evidence showing that the toxicity of an oil to this insect has been increased by the addition of a solute.

The great increase in interest in the use of rotenone-bearing roots and their extractives as insecticides has led to investigations which indicate considerable promise in the use of these materials, combined with oil, in the control of the red scale. For several years these investigations have constituted an important part of the general research program on insecticides in the entomological laboratories of the Citrus Experiment Station.

After testing a number of solvents, La Due (1938) concluded that methyl-n-amyl ketone offered greatest promise as a mutual solvent for the extractives of rotenone-bearing roots and spray oils. Many apparently promising solvents had to be discarded because, while otherwise satisfactory, their water solubility was too high and they did not remain in the oil phase in the diluted spray material.

Trials with 10 per cent by weight of derris resins[4] in methyl-n-amyl ketone, used in the proportion of 1 part of toxic solution to 15 parts of oil, met with considerable success in both laboratory and field work in 1936. The addition of the toxic solution to the spray oil resulted in a suspension, and possibly a partial solution, of the derris resins in the oil. In 1937, dibutyl phthalate, which had already been used by Smith (1932a) as a mutual solvent for oil and rotenone, was substituted for methyl-n-amyl ketone because, at least in high concentrations of toxic solution, the derris resins were then completely dissolved in the oil. For application against red scale, however, a higher concentration of oil is required than for application against other scale insects on citrus, and any economically feasible amount of toxic solution must therefore be more diluted in the oil.

When 10 per cent by weight of derris resins in dibutyl phthalate was used in the proportion of 1 part of the dibutyl phthalate-resin solution to 15 parts of oil, and when this oil-toxicant was then used at 2 per cent concentrations, the derris resins appeared to be partly in suspension and partly in solution. Better results were obtained later with 5 per cent derris resins in dibutyl phthalate, used in the proportion of 1 part of dibutyl phthalate-resin solution to 7 parts of oil. This dilution, with the same amount of derris resins as before, but with twice as much solvent, resulted in a more nearly true solution.

The solubility of derris resins in oil increased with (1) increasing ratio of toxic solution to oil, (2) increasing "heaviness"[5] of the oil, provided the percentage of unsulfonatable residue was constant, (3) decreasing percentage of unsulfonatable residue in the oil, and (4) increasing number of carbon atoms in the ketones and esters which were used as mutual solvents. Thus dibutyl phthalate was found to be more effective than ethyl phthalate, but less effective than isoamyl phthalate, as a mutual solvent for derris resins and oil. The mutual solvent should, of course, have as low water solubility as possible.

Attempts to increase the effectiveness

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[3] The writer wishes to acknowledge the valuable advice and aid of his colleagues at the University of California Citrus Experiment Station and, also, the very able assistance of Lewis Wilson, of the Works Progress Administration.

[4] Dry extract of derris root containing 25 per cent rotenone.

[5] Based on the percentage of oil distilled at 636 degrees F.

of oil sprays by the addition of finely divided solids have already been reported (Ebeling 1935, 1936). Small particles of paraffin wax were used in these tests, but certain practical difficulties in the use of wax suspensions, as well as a certain amount of tree reaction, led to investigations with other finely divided solids, both organic and inorganic. Promising results with these materials prompted a more extensive report (Ebeling 1938) on certain aspects of the behavior of spray oil on various morphological parts of the citrus tree. This report also explained the principle underlying the addition of finely divided solids to oil to influence its behavior favorably and effect an increase in the insecticidal efficiency of the oil per unit deposited on the tree surface. Further work has been done in this field of investigation recently, and finely divided solids have been investigated along with toxicants in experiments the results of which are reported in the present paper.

EXPERIMENTAL PROCEDURE.—In preliminary work with dibutyl phthalate as a mutual solvent for derris resins in spray oil, red scale-infested lemons were sprayed with this material by means of a laboratory precision sprayer. The results showed sufficient promise to warrant extensive experimentation. Laboratory methods were then discarded because of the difficulty experienced in obtaining statistically reliable data from the necessarily small samples used in laboratory experimentation.

The variation in population density of the red scale on different fruits, or even on different parts of the same fruit, appeared to be the most important factor contributing to variability of results. (The influence of population density on the insecticidal efficiency of spray oil will be discussed in a later section of this paper.) It appeared that the variability in results would be overcome only by the segregation of population densities among great numbers of insects, practicable only in field experiments.

In field experiments, moreover, the effectiveness of the spray on all parts of the tree can be observed. The greatest difficulty in the control of the red scale is experienced on the branches of the tree, for the oil soaks into the rough bark so rapidly that there is not sufficient oil left to penetrate beneath the bodies of the scales, where it is most effective (Ebeling 1936). Tree branches cannot be conveniently sprayed in the laboratory and stored for the six weeks' or two months' period required before it can be easily determined whether the scales are alive or dead.

Lemon orchards heavily infested with red scale were selected, and counts were made both on the fruit and on the branches to determine the natural mortality previous to treatment. In calculating the "percentage of survival" referred to in the present paper, account is taken of the natural mortality at the time of treatment. Counts were made six weeks to two months after the plots were treated. For convenience and to avoid confusion and error, only adult female insects were counted to determine the effect of treatment. Greater difficulty is experienced in killing the adult female red scales with oil than in killing the immature scales.

A period of several weeks sometimes elapses before red scale succumbs to oil spray (Ebeling 1936); consequently, in a six weeks' period, the delayed effects of oil become apparent, and the insects become sufficiently dried out so that counts of dead and live insects can be made rapidly without appreciable error.

A unit on which counts were made consisted of two inches of a branch, as seen from one aspect, or one infested fruit. Twenty such branch units and 20 infested fruits were examined per tree, and 10 trees were examined in each plot. According to this method of counting, usually from 3,000 to 5,000 insects were counted on the branches, and as many as 30,000 insects were counted on the fruit in each plot.

A power sprayer developing 450 pounds pressure, with agitation sufficient for tank-mixture spraying (Smith 1932b) and with eight sixty-fourths-inch disks in the nozzles, was used for spraying. In all experiments the sprays were applied in accordance with what is considered a good commercial application.

DETERMINATION OF OIL DEPOSIT.—No adequate estimate of the increase in effectiveness of oil sprays through the addition of toxicants or solids can be made without a knowledge of the effect of the added materials on the oil-depositing properties of the spray. If the added materials increase oil deposit, the greater mortality resulting from the spray can-

not be attributed to the increased insecticidal efficiency of the spray. On the other hand, if greater mortality is obtained with no increase in oil deposit or with a decrease in oil deposit, the insecticidal efficiency of the spray has been increased by the added material.

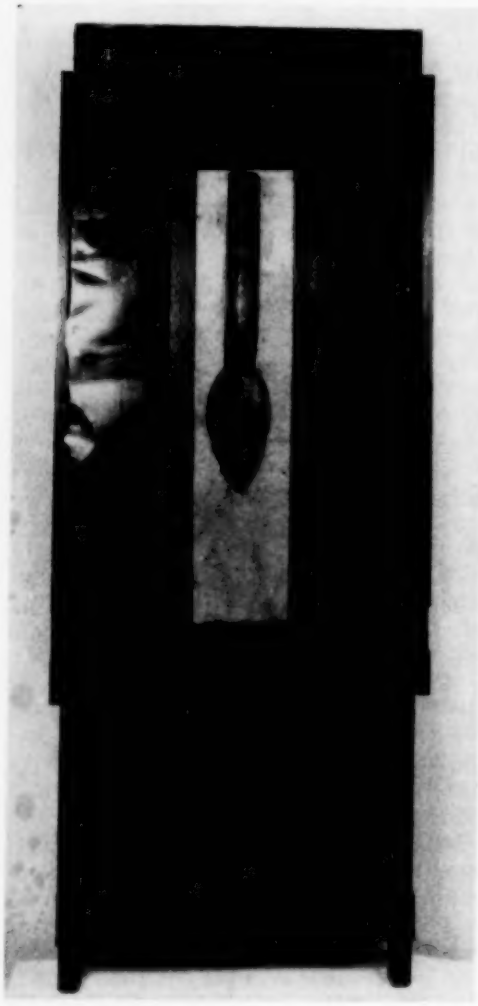

FIG. 1.—Apparatus for holding a leaf during the spraying process. The leaf is held by a steel spring clamp attached to a plate of sheet metal which slides in grooves in the laths on each side of the plate. Arms on each side hold the apparatus in position. The clamp is operated indirectly by means of a foot pedal; thus both hands of the operator are left free to remove sprayed leaves and to place new leaves in the clamp.

In the majority of cases heretofore, oil-deposit determinations have been made by extraction of the oil from the leaves by means of a rather involved procedure (Rohrbaugh 1934). One of the criticisms of this procedure is that after oil has already penetrated a leaf, a complete recovery of the oil cannot be made. Plant waxes and essential oils in the leaves also increase the possibility of error in an extraction method. Swain and Green (1933) washed the surfaces of sprayed leaves with methylene chloride and, after evaporation of the solvent, determined gravimetrically the amount of oil washed off. The spray water was allowed to evaporate before the leaves were washed. Tihenko and Hensill (1937) avoided loss from evaporation and penetration by washing the leaves immediately with acetone, which removed both oil and water. Acetone, however is a very inefficient solvent for oil compared with the more non-polar compounds.

To determine the oil-depositing properties of the sprays used in the present experiments, large grapefruit leaves averaging about 45 square centimeters in area, were used. The upper surface of each leaf was wiped with a dry cloth, to remove the dust, and was then sprayed from a distance of 3.5 feet, the leaf being held in place by a steel spring clamp (figure 1). The spray was applied by means of a laboratory power sprayer with 300 pounds pressure and with a three sixty-fourths-inch disk in the nozzle. Each leaf was exposed to the spray for 5 seconds, and 50 leaves were sprayed in each test lot.

After the leaves had been sprayed, they were fastened to boards with thumb tacks and were kept in a cool, dark basement room for 2 to 4 hours, until the water was dried off. The amount of oil which penetrates the upper surface of the leaf in this period of time is negligible, since no stomata occur on the upper surface (they are all located on the lower surface). Since leaf cuticle is somewhat polar in nature (Ebeling 1938), the penetration of oil into the cuticle is extremely slow. The first signs of oil penetration, as evidenced by a darkening of the leaf, are noticed along the midrib and veins of the leaf; but even this type of penetration does not take place within the period mentioned, if the leaves are dried in a cool, dark room. Light has the effect of increasing the rate of penetration of oil into citrus foliage (Ebeling 1938).

After the leaves were dry, the portions which had been held by the clamp during the spraying operation were cut off, and the remaining portions were held at their upper edges and washed with petroleum ether (boiling range 30 degrees to 60 degrees C.), the washings (about 200 cubic centimeters) being caught in a 600 cubic centimeter beaker. The liquid was filtered through a Gooch crucible by means of a suction filter flask, then transferred back to 600 cubic centimeter beakers, and the solvent was evaporated on a water bath heated to 70 degrees C., until only 10 to 20 cubic centimeters of liquid remained. This was transferred to 50 cubic centimeter beakers, and the solvent was evaporated on a water bath until the ether was all evaporated and only the spray oil remained. The beaker and spray oil were then cooled and weighed, and the weight of the beaker was subtracted from the resulting figure to obtain the weight of oil.

The outlines of the washed leaves were traced on sheets of paper and areas were determined by means of a planimeter. The weight of oil was calculated in grams per thousand square centimeters of leaf surface. A correction was then made for the amount of wax washed off the leaves along with the oil. This was determined by a blank test to be 17 milligrams per thousand square centimeters of leaf surface.

A test was made to determine the variation in deposit of oil on grapefruit leaves sprayed with the same amount of oil and having the oil residue washed off (1) at identical periods after spraying and (2) at different periods after spraying. Five lots of 50 leaves each were sprayed and then tacked to boards. Three of the lots were dried in a dark basement at 23 degrees C. for 2 hours and 35 minutes before the oil was washed off with petroleum ether, the fourth lot was left in the basement for 5 hours and 30 minutes, and the fifth lot was dried in the sun at 30 degrees C. for 1 hour and 45 minutes. The amount of residual deposit, including plant wax and plant oil as well as the oil used in the spray, is shown in table 1.

It appears from these data that the longer the period between spraying and residue removal, or the higher the temperature, the greater is the amount of residue removed by the petroleum ether. This is probably the result of the softening effect of the oil on the leaf-surface wax, which is the more readily washed off by the solvent. The longer the oil remains on the surface, the greater is the percentage of leaf wax and leaf oil which may be expected in the residue.

In another experiment, however, oil-sprayed leaves which were washed with petroleum ether 2 hours after treatment yielded 0.498 gram of residue per thousand square centimeters of leaf surface. The oil was then sulfonated, to remove

**Table 1.—Variation in amount of residual deposit removed from the upper surfaces of grapefruit leaves at various periods after spraying.***

| Lot No. | Drying Treatment | | | Total Residual Deposit (In Grams) |
|---|---|---|---|---|
| | Place | Temperature in Degrees C. | Time | |
| 1 | Dark basement | 23 | 2 hrs., 35 min. | 0.233 |
| 2 | Dark basement | 23 | 2 hrs., 35 min. | 0.228 |
| 3 | Dark basement | 23 | 2 hrs., 35 min. | 0.237 |
| 4 | Dark basement | 23 | 5 hrs., 30 min. | 0.249 |
| 5 | In sun | 30 | 1 hr., 45 min. | 0.250 |

* The upper leaf surfaces were sprayed with 2 per cent medium oil with blood albumin spreader.

plant oils and waxes, and centrifuged with sulfuric acid by J. P. La Due,[6] who used an improved method for oil-residue determination, based on that of Tihenko and Hensill (1937). After this treatment, 0.570 cubic centimeter of oil remained. Since the specific gravity of the oil was known and a correction could be made for the coefficient of expansion of spray oil at 60 degrees C., the temperature at which the oil was centrifuged, the weight of oil could be calculated and was found to be 0.480 gram. Thus 0.018 gram of residue was removed by the sulfonation process. This is very nearly the same amount of plant wax as that which was washed off the upper surfaces of grapefruit leaves in blank tests. In two such tests, in June 7 and July 20, 1939, the yields of residue were, respectively, 0.0176 gram and 0.0172 gram per thousand square centimeters of leaf surface. Although more rapid drying of the leaves can be accomplished by the use of currents of air, the previously described experiment shows that very little plant oil and wax is washed off the leaves even if 2 hours elapse after treatment before the residue is washed off.

The method used by the writer is simple and rapid and does not require the use of a centrifuge, as does a volu-

[6] Laboratory Assistant in the Experiment Station.

metric method such as that of Tihenko and Hensill (1937). Sulfonation of the oil residue is also considered unnecessary, for the amount of plant wax and plant oil washed off the leaves during the very brief washing to which the leaves are subjected can be determined by a blank test, and a correction factor for all tests of a series can be thereby determined. The writer believes, also, that the method has

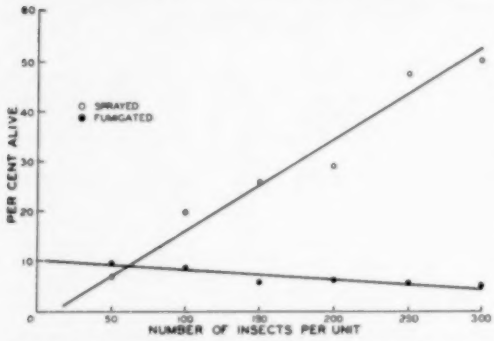


FIG. 2.—Survival curves of sprayed and fumigated red scale on lemons, as influenced by population density. The spraying was done with a proprietary oil at 2.5 per cent concentration, and the fumigation, with a 22-cubic centimeter schedule of hydrocyanic acid gas.

an important advantage over others in that only the upper surface of the leaf is sprayed; consequently, no appreciable amount of oil is lost by penetration. On the other hand, oil penetration on the lower surface is very rapid and in some cases takes place in a few minutes; it is also very variable, changing with the intensity of the light and the diurnal respiratory activity of the leaf (Ebeling 1938).

INFLUENCE OF POPULATION DENSITY ON THE INSECTICIDAL EFFICIENCY OF SPRAY OIL.—The great difficulty experienced in controlling heavy infestations of red scale has been observed by a number of investigators. Since 1930, the writer has kept records of the percentage of mortality of red scale at various population densities, both on the fruit and on the branches of lemon trees. On the basis of counts of over a million insects, it was determined that in the plots where the percentage of mortality of adult red scale was above average, there were only about one-fourth as many insects per unit area on the branches and one-third as many on the fruit before treatment as in the plots where the percentage of mortality was below average. Knight (1932) published data on the use of oil spray against red scale on lemon fruits and showed that the effectiveness of the spray decreased with increase in population density of the insects. Cressman and Dawsey (1934) showed that the same was true with regard to adult camphor scales, *Pseudaonidia duplex* (Ckll.), on potted camphor plants.

Figure 2, which is based on an examination of 21,983 adult red scales on mature lemon fruits according to the procedure described in a preceding section of this paper, shows the increasing percentage of survival of red scale sprayed with 2.5 per cent of a proprietary spray oil in a heavily infested lemon grove in 1931. The percentage of survival in the various population groups varied from 7.6 per cent on lemons having 50 or less adult scales per fruit, to 50.5 per cent on lemons having 251 to 300 adult scales per fruit. A fumigation treatment with hydrocyanic acid gas (22-cubic centimeter schedule) resulted in approximately the same percentage of mortality of scales on fruits with 50 or less insects as resulted from the oil-spray treatment, but the effectiveness of the treatment did not decrease with increasing density of the scales, as was the case with the oil spray. The slight de-

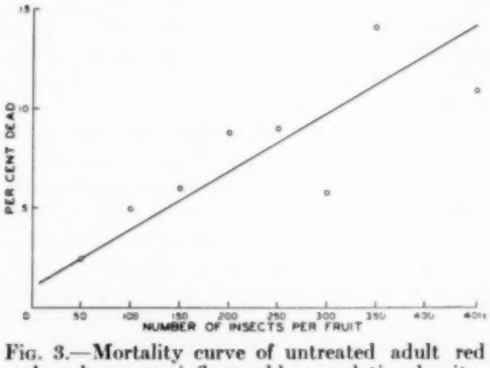


FIG. 3.—Mortality curve of untreated adult red scale on lemons, as influenced by population density.

crease in percentage of survival at higher population densities when hydrocyanic acid gas was used can be accounted for by the concomitant increase in natural mortality, as shown in figure 3.

The thin film of oil normally deposited on the scales by oil spray is not sufficient to kill the insects (Ebeling 1936). Consequently, the scales must, by capillary

action, draw additional oil off the surface of the tree around their bodies (Ebeling 1938); and in doing so they draw oil from one another if the population is dense. If less crowded the scales can draw oil off a larger area of tree surface, and there is, accordingly, more oil per unit deposited available for each insect. When fumigated with hydrocyanic acid gas, each insect has access to the same amount of gas, regardless of the number of insects; therefore population density does not influence the effectiveness of the treatment.

Since the population density varies from plot to plot, a comparison of the mean percentages of survival in different plots might not give a true indication of the relative effectiveness of the treatments. However, the percentages of survival in the corresponding population-density groups of different plots can be compared, or the survival curves based on the percentage of survival in the various population densities can be compared. Hence the data shown in this paper are presented in charts, with points representing the percentages of survival in various population groups and survival curves based on these points.

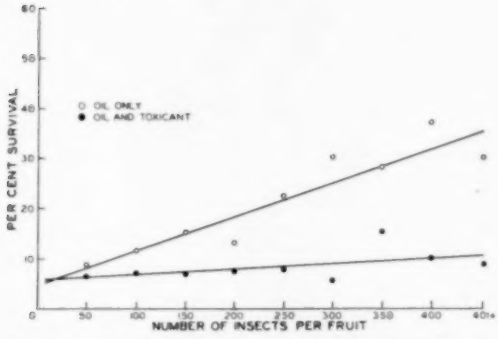


FIG. 4.—Survival curves of adult red scale on lemons sprayed with 2 per cent medium oil, with and without 6.25 per cent of a toxic solution of 10 per cent derris resins in dibutyl phthalate.

EXPERIMENTS WITH TOXICANTS.—Although many toxicants have been investigated by the writer since 1930, for the sake of brevity the following data will pertain only to derris resins (25 per cent rotenone) added to oil by means of mutual solvents. Figure 4 shows the survival curves of adult red scale on lemons sprayed with 2 per cent medium oil,[7] with and without 6.25 per cent of a toxic solution of 10 per cent derris resins in dibutyl phthalate. The mean percentage of survival was 19.6 in the plot treated with oil alone and 8.3 in the oil-toxicant-treated plot. The mean percentages of survival on the branches of the trees in the same plots were 32.5 and 16.4, respectively. These differences are highly significant, as can be seen in figure 4.

[7] Distillation at 636 degrees F. 46 per cent, viscosity 58 seconds Saybolt, unsulfonatable residue 92 per cent.

FIG. 5.—Red scales removed from a lemon leaf and placed on their backs to show the ventral mass of waxy threads between the scale body and its substratum. The scale on the right was sprayed with oil which penetrated the mass of wax and the spiracles of the insect and caused the wax to become translucent. The waxy threads make an excellent capillary system, which draws the oil off the tree surface around the insect's body.

The oil was used according to the tank-mixture method (Smith 1932b), with 4 ounces of blood albumin spreader per 100 gallons of spray. The deposit of oil on the leaves was 0.353 gram per 1,000 square centimeters of upper leaf surface, according to the aforementioned method for determination of oil residue. The deposit of oil-toxicant was 0.208 gram per 1,000 square centimeters of dorsal leaf surface. No blood albumin spreader was used with the oil-toxicant mixture. It is of interest to note that a greater mortality of adult red scales resulted from the toxic oil spray than from the spray containing oil alone, despite the much lower deposit of oil with the oil-toxicant mixture.

EXPERIMENTS WITH FINELY DIVIDED SOLIDS.—Beneath the body of a red scale can be found a mass of wax composed of loosely woven threads secreted from the pygidium of the insect (figure 5). This mass of wax is capable of absorbing much oil, and the oil must penetrate the wax before it can reach the spiracles of the insect which are somewhat centrally lo-

cated. As oil is absorbed by the scale, more oil is drawn under its body by capillary attraction. On much of the tree surface, however, the oil has a relatively high contact angle (figure 6) and cannot be easily withdrawn because it does not form a continuous film. Even on the rough bark of the larger branches, where the contact angle of oil is much lower, the rate of

FIG. 6.—The gathering of oil into irregular masses on the upper surfaces of lemon leaves sprayed with 2 per cent light-medium oil emulsion. This is typical of the behavior of spray oil on surfaces upon which it has a relatively high contact angle. Drawings traced from photographs by Dr. L. J. Klotz. ×37.

penetration of the oil into the tree is so rapid that very little can be drawn off the surface by the body of the scale. It is especially on the bark, in fact, that a means of facilitating the movement of the oil over the surface is needed.

Unfortunately, the surface tension of oil cannot be appreciably lowered by the addition of surface-active solutes. According to Langmuir and Harkins (Clark 1939), the surface tension of a liquid depends on the structure of the surface layer of atomic groupings. The liquid hydrocarbons have methyl groups at the ends of their chains and have, consequently, an approximately constant surface tension, regardless of the length of the chains (Clark 1939). Any compound to be dissolved in oil must be organic and therefore so oriented that the atomic group on the surface is the methyl group and the surface energy at least does not differ greatly from that of oil alone.

The behavior of oil on the tree surfaces, however, depends not only on its own surface tension, but also on the surface tension of its substratum. The surface tension on the tree surface may be greatly increased by an increase in the surface area per unit distance. This may be accomplished by the deposition of finely divided solids on the tree surface with the oil. The oil can then no longer, by virtue of its own surface tension, gather in masses, as shown in figure 6; and its gradual withdrawal from the surface as it is absorbed by the body of the scale insect is thus facilitated. The finely divided solids may be considered as a wick facilitating the movement of oil over the surface of, rather than into, the porous bark.

Figure 7 shows that oil containing solids may be withdrawn from the entire surface of the leaf by continuously withdrawing it at one point. In this case the oil was withdrawn from the leaf surface by allowing it to penetrate into a slit cut in the cuticle, from which it spread

FIG. 7.—Effect of finely ground plant fiber on the spread of spray oil on the upper surface of a clean lemon leaf. The left half of the leaf was painted with straight oil, the right half, with oil containing 2 per cent apricot-pit flour. Arrows point to incisions made through the cuticle on both halves of the leaf, and the white line shows edge of discolored area made by the flowing of the oil into the incision on the right half of the leaf and its spreading through the interior of the leaf. The oil has been completely drawn off the surface on the right side of the leaf into the incision. Oil containing finely divided solids can similarly be drawn off the surface of a leaf by means of a blotter. ×⅔.

throughout the interior of the leaf. The oil may also be withdrawn by means of a

blotter standing on edge. The blotter will not withdraw a layer of oil on a leaf surface on which finely divided solids have not been deposited, however, for on such a surface oil has a tendency to gather into small masses rather than to spread.

Experiments with inert solids have been confined almost entirely to finely ground plant fibers because they are preferentially wet by oil, whereas inorganic materials may be as readily wet by water as by oil and may change from the oil to the water phase in the spray mixture. Some experiments, however, were made with bentonite. Ten pounds of bentonite were used to emulsify 10 gallons of oil with 10 gallons of water, and the resulting mixture was used at 4 per cent concentration with blood albumin as the spreader. A layer of bentonite was deposited on the tree surface, but the mortality of red scales was less than that with the same amount of oil used without bentonite. The bentonite had "tightened" the emulsion and greatly reduced the deposit of oil by the spray mixture.

Experiments were made mainly with walnut-shell flour ground to such a consistency that not more than 5 per cent was retained on a 200-mesh screen, but about 60 per cent was finer than 325 mesh. These tests were made with a medium oil at 2 per cent concentration. Three pounds of walnut-shell flour were mixed with 2 gallons of oil in a measuring can by means of a paddle. Apricot-pit flour and cherry-pit flour used at the same concentration seemed to increase the effectiveness of the oil as much as walnut-shell flour (figure 8).

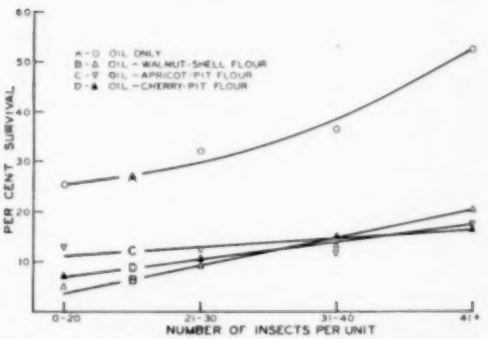


FIG. 8.—Effect of different types of finely divided organic solids on the efficiency of a medium-emulsive spray oil used at 1.75 per cent concentration. Counts made of adult red scales on the branches of lemon trees.

Emulsive oils[8] were used in the tests with organic solids. The solutes in the oil increased the tendency of the solids to remain in the oil phase as the oil was being agitated with water in the spray tank. When the solids are mixed with oil not containing the desirable solutes, they leave the oil, to a large extent, and go into

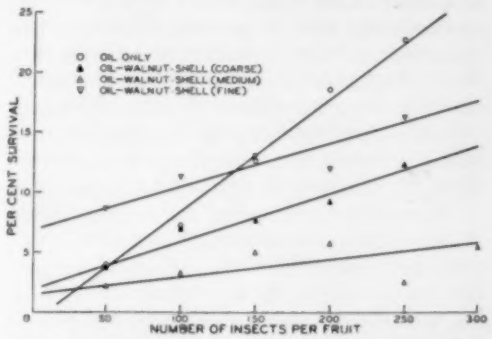


FIG. 9.—Effect of walnut-shell flour of three different particle sizes on the efficiency of oil spray used against adult red scale on lemons. Three pounds of walnut-shell flour were mixed with 2 gallons of oil for each 100 gallons of spray.

the water phase. The tendency of the solutes used in emulsive oils to keep the solids in the oil phase is probably largely due to the effect of these solutes in decreasing the interfacial tension oil/water. When the interfacial tension water/solid is greater than the interfacial tension oil/water plus the interfacial tension oil/solid, the solid stays entirely in the oil (Clayton 1928). Since the solutes in the oil do not alter the interfacial tension water-solid, but reduce the interfacial tension oil/water and oil/solid, their effect is to increase the tendency of the solid to remain entirely in the oil phase, despite the large proportion of water and the violent agitation in the spray tank. The solids are consequently deposited on the tree surface with the oil, whereas if they were in the water, they would, to a large extent, be lost with the water running off the tree in the spraying process.

Not all ground plant fibers are satisfactory, however. It was found that redwood flour actually decreased the effectiveness of an oil spray, probably because it is so absorptive that it retains much of the oil, which is consequently not available to the insects. When 3 pounds

[8] Spray oils containing usually less than 1 per cent of an oil-soluble emulsifier which affects certain physical properties of the oil, notably its interfacial tension with water.

of walnut-shell flour are mixed with 2 gallons of oil, the resulting mixture is very fluid; but when 3 pounds of redwood flour are mixed with 2 gallons of oil, the resulting mixture is almost a paste and the deposit of oil when this material is used in a spray is very light.

Even in non-absorptive materials such as walnut-shell flour, there appears to be an optimum size of particle. Thus, in the experiments the results of which are shown in figure 9, the "fine" walnut-shell flour (5 per cent retained on a 325-mesh screen) added nothing to the effectiveness of a 2 per cent concentration of emulsive-oil spray; in fact, it seemed to reduce the oil deposit considerably. A "coarse" flour (5 per cent retained on a 100-mesh screen) definitely increased the effectiveness of the oil spray; and the "medium" flour, known commercially as C-200 (5 per cent retained on a 200-mesh screen), increased the effectiveness of the oil to an even greater extent.

The effect of finely divided solids on the oil-depositing properties of a spray should be considered in an evaluation of the relative merit of these solids. In a test for oil deposit in which 2 per cent medium oil containing 6.25 per cent dibutyl phthalate with 5 per cent derris resins was used, the oil-toxicant deposited 0.208 gram of oil per 1,000 square centimeters of upper leaf surface, while the same amount of oil-toxicant with the equivalent of 3 pounds of walnut-shell flour, C-200, per 2 gallons of oil (18 grams per 100 cubic centimeters) deposited 0.259 gram of oil per thousand square centimeters. Thus the walnut-shell flour caused an increase of about 25 per cent in oil deposit. In another test, with greater velocity and volume of spray, 2 per cent medium oil-toxicant deposited 0.442 gram of oil per thousand square centimeters of upper leaf surface, while 2 per cent medium oil-toxicant with the equivalent of 3 pounds of walnut-shell flour per 2 gallons of oil deposited 0.445 gram of oil per thousand square centimeters.

From these results it may be inferred that the walnut-shell flour may or may not increase the deposit of oil. In the orchard, however, a large number of leaves from each of two plots may be compared for oil deposit by examining their ventral surfaces, where the oil penetrates rapidly and causes a dark discoloration. If the leaves from two plots, *A* and *B*, are examined simultaneously in pairs, the number of times the leaves from plot *A* show more (or less) discoloration from oil than the leaves from plot *B* can be recorded, and from these figures the relative oil-depositing abilities of the two sprays can be statistically evaluated. According to this method of oil-deposit evaluation, the walnut-shell flour caused a deposit of oil significantly higher than that left by oil-toxicant sprays containing the same amount of oil-toxicant but no walnut-shell flour. It did not, however, appear to increase the deposit of emulsive oils, although it increased their insecticidal efficiency. When added to low dosages of oil-toxicant, the walnut-shell flour also increased the effectiveness of the spray above that of sprays containing higher dosages of oil-toxicant and depositing obviously more oil.

According to the field method of oil-deposit evaluation, as described, the oil sprays were found to deposit a much greater quantity of oil than the oil-toxicant sprays used in the present series of experiments.

The amount of walnut-shell flour used in these tests (3 pounds per 100 gallons of spray mixture) was entirely arbitrary and it is possible that further experimentation will show that some other amount may be optimum for greater effectiveness. There is some indication, based on preliminary data, that 2 pounds of walnut-shell flour per 100 gallons of spray mixture may prove to be as effective as 3 pounds in increasing the efficiency of oil spray against the red scale.

WALNUT-SHELL FLOUR COMBINED WITH OIL-TOXICANT.—Since toxicants and solids each increased the effectiveness of spray oil, experiments were made to determine whether a combination of toxicants and solids would increase the effectiveness of the oil to a greater extent than either the toxicants or the solids alone. The dibutyl phthalate, in which the derris resins were dissolved, caused the oil to become "emulsive"; the walnut-shell flour was then added to the oil and remained in the oil phase in the spray mixture. Consequently straight spray oil[9] was used according to the tank-mixture

[9] Spray oil to which nothing has been added.

method (Smith 1932b), except that blood albumin was not used.

The results of one experiment are shown in figure 10. The oil-toxicant mixture contained 1 part of dibutyl phthalate with 5 per cent derris resins in 7 parts of

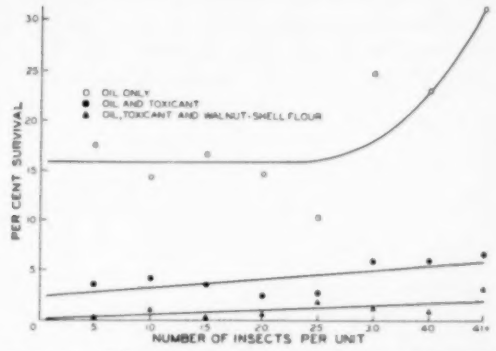


FIG. 10.—Effectiveness of an oil-toxicant spray and an oil-toxicant-flour spray used against adult red scale on the branches of lemon trees. The concentration of oil and oil-toxicant was 2 per cent, and the walnut-shell flour was mixed with the oil-toxicant at the rate of 3 pounds to each 2 gallons.

medium oil. This made a clear solution instead of a suspension such as resulted from the 1 to 15 dilution. The oil-toxicant resulted in a 3.9 per cent survival on the branches compared to a 21.2 per cent survival in the plot sprayed with oil alone. With 3 pounds of walnut-shell flour in 2 gallons of oil-toxicant, the percentage of survival was reduced to 0.98. Counts on the fruits showed that although there was a survival of 14.4 per cent in the plot sprayed with oil alone, there was only a 2.5 per cent survival in the oil-toxicant-sprayed plot and 1.2 per cent survival in the plot sprayed with oil-toxicant and walnut-shell flour. According to "Student's" $t$ test, both on the branches and on the fruit, all differences were significant with $P = 0.01$.

The preceding experiment was repeated with the same amount of derris resins per gallon of oil, but with the derris resins dissolved in *Cardolite* 627[10] as a 10 per cent solution, and 1 part of toxic solution was used with 15 parts of oil. The derris resins were heated with *Cardolite* 627 until dissolved; this solution was then heated with 3 to 5 parts of oil to make a stock solution which could be diluted with oil in the stated proportions and remain in a clear solution. Two per cent medium oil-toxicant was used in the spray, and this resulted in a survival of 7.3 per cent of the adult insects on the branches, as compared to 17.6 per cent when straight oil was used at 2 per cent concentration with blood albumin spreader. Where oil-toxicant and walnut-shell flour (3 pounds per 100 gallons of spray) were used, the survival on the branches was 4.4 per cent.

[10] According to information given by the manufacturers, this is a formaldehyde reaction product of cashew nut-shell liquid. It is an oil-soluble, heat-reactive type of resin.

SUMMARY.—Within recent years, attempts to increase the effectiveness of oil spray against the California red scale by the addition of derris resins (25 per cent rotenone) in suitable mutual solvents, have shown sufficient promise to warrant further investigation.

In orchard experiments, counts were made of the natural mortality prior to treatment, and the percentage of survival of adult female scales was recorded after treatment. Counts were made of dead and live scales on 20 fruits and 20 units of branches on each of 10 lemon trees in each plot. A branch unit consisted of 2 inches of an infested branch as seen from one aspect. Only adult female scales were examined.

The effectiveness of oil spray decreases as the population density increases; therefore, "survival curves" were prepared to show the relation of percentage of survival to population density. A comparison of the survival curves shows the relative effectiveness of the treatments.

In order to correlate the depoist of oil with the effectiveness of the various sprays, a method was developed by which the upper surfaces of each of 50 leaves were sprayed. After the water had evaporated from the leaves, the oil was washed off with petroleum ether. The oil and solvent were then filtered, the ether was evaporated by heat, and the oil was weighed in 50-cubic centimeter beakers.

The oil-toxicant sprays, in which 10 per cent derris resins in dibutyl phthalate were added to oil in the proportion of 1 part of toxic solution to 15 parts of oil, deposited much less oil than the sprays containing the same amount of oil but no toxic solution. However, despite the lower oil deposit, the oil-toxicant sprays resulted in a greater mortality of red scale.

The addition of walnut-shell flour to emulsive oil resulted in an increase in the

effectiveness of the oil against the red scales without increasing oil deposit. When the walnut-shell flour was added to the oil-toxicant solutions, their effectiveness was also increased. Thus the addition of 1 part of a 5 per cent solution of derris resins in dibutyl phthalate to 7 parts of medium oil at 2 per cent concentration resulted in a survival of 3.9 per cent of adult female insects on the branches of lemon trees, as compared to a survival of 21.2 per cent when the oil was used alone at 2 per cent concentration. When 3 pounds of walnut-shell flour were added to 2 gallons of the oil-toxicant, however, only 0.98 per cent of the insects survived the treatment. Similar increases in the effectiveness of the oil by the addition of toxicant and walnut-shell flour were shown by counts made on the fruits.

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# Factors Concerned in the Deposit of Sprays

## *VII. Design and Use of a Photographic Apparatus for Studying the Impact and Movement of Individual Drops Upon a Surface**

W. M. UPHOLT† and W. M. HOSKINS

Dynamic methods for studying the behavior of insecticidal spray liquids have received increasing attention in recent years. In this laboratory an effort has been made to relate the deposit of solid and liquid insecticides to the behavior of sprays as they strike the surface. In order to avoid the extremely complicated conditions prevailing during the application of the multitude of drops which constitute a spray, an attempt has been made recently to study the behavior of single drops of any desired liquid as they strike a chosen surface. The present report concerns a photographic method which appears to have unique advantages and is being used successfully in studies on the mutual effects of liquid and solid upon wetting and spreading.

The photographing of drops during im-

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pact is, of course, not a new method of investigation; astonishingly fine pictures at several stages of the process were made many years ago by Worthington (1895). Recently, Edgerton, Germeshausen and Grier (1937) have used a high speed motion picture camera for recording the phenomena brought about by allowing a drop of water to strike a liquid surface.

APPARATUS AND OPERATION.—The essential feature of the apparatus to be described is that a freely falling drop of liquid intercepts a light beam directed upon the sensitive element of a photocell and thereby brings into action a relay which, after a predetermined time delay, fires a spark between two magnesium electrodes. By the light of the discharge

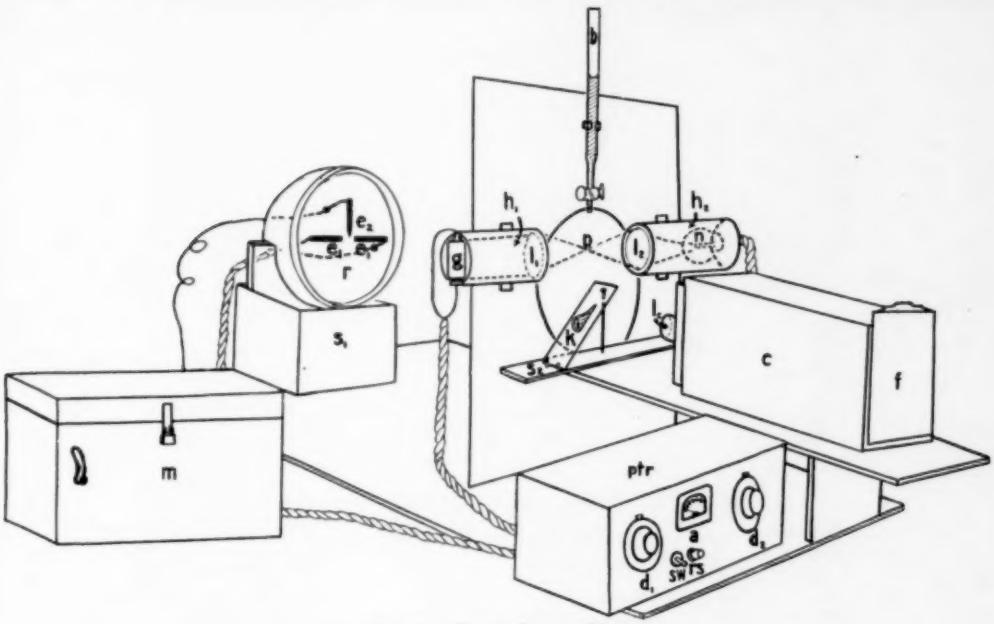



FIG. 1.—General assembly.

| | | | |
|---|---|---|---|
| a | 0–1 Milliammeter | k | Solid Surface |
| b | Burette | $l_1$, $l_2$ | Lens |
| c | Camera | $l_3$ | Lens for Camera |
| $d_1$ | Potential Control Dial | m | Box Housing Spark Illuminator Mechanism |
| $d_2$ | Time Delay Control Dial | n | Mazda Lamp 32 c.p. |
| $e_1$, $e_1$ | Mg Electrodes | p | Point of Focus |
| $e_2$ | Impulse Electrode | r | Reflector |
| f | Film Holder | rs | Reset Switch |
| g | Photoelectric Cell (RCA-922) | $s_1$ | Support for Reflector |
| $h_1$ | Housing for Photo Tube | $s_2$ | Support for Surface |
| $h_2$ | Housing for Light Source | sw | Switch |
| i | Drop | | |

ptr Photoelectric trigger relay.

However, the only application of the method to the problem of the wetting and spreading of insecticidal liquids seems to be that of Hoskins and Ben-Amotz (1938). In that work the length of exposure was regulated by a slot in a large rotating metal circle and illumination was given by a flash bulb. The procedure was somewhat uncertain in operation and expensive for use on a large scale. Hence a new apparatus was developed which is comparatively easy to construct and inexpensive to operate.

the drop, which has meanwhile made contact with a horizontal or inclined solid, may be photographed from any desired angle. Figure 1 shows the various parts in place for taking silhouettes of drops upon an inclined slide. The wiring diagram for the spark illuminator system is shown in figure 2. This is a simplified modification of that given by Edgerton, Germeshausen and Grier (1937). The magnesium rod electrodes, $e_1$ and $e_1$, are set far enough apart so that the 2,000 volt condenser is just unable to discharge. The point of a

third electrode, $e_3$, is set at the gap and is connected with an ordinary spark coil. When the latter is discharged a small spark passes from the third electrode to one of the main electrodes and enough ionization of the air occurs to permit the large condenser to discharge. The duration of the flash is extremely short, not longer than one-ten thousandth of a second, and accordingly no rapid shutter is required for the camera. The light is strong enough to permit the use of ordinary film having a Weston rating of 20. Hence by working in a moderately darkened room it is possible to leave the shutter of the camera open for a short time before and after the picture is taken.

The discharge from the third electrode can be brought about by any switch or relay but for timing with the accuracy desired manual control is not possible. Hence the photocell and trigger relay mentioned before were used.

The wiring diagram is shown in figure 3. Briefly, the operation is as follows. With the light from the 32 candlepower lamp directed upon the photoelectric cell, pec, (see also figure 1) the potential of the grid in tube $t_1$ is adjusted so that the potential of the grid in tube $t_2$ (the first Thyratron tube) just prevents discharge of the tube. When the light to the photocell is interrupted momentarily by the passage of a drop through the point of focus, p, in figure 1, the resultant change in current from the photocell alters the grid potentials in tubes 1 and 2, causing the latter tube to discharge and build up a potential in the condenser, c. When the condenser charge reaches a certain magnitude it causes the second Thyratron tube, $t_2$, to discharge through the primary circuit of the spark-coil ($a_3$ in figure 2). The resulting spark from the auxiliary electrode ($e_2$ of figures 1 and 2) then enables the main condenser to discharge through electrodes $e_1$ and $e_1$ as described before. The whole process from interruption of the light by a falling drop to discharge of the spark takes place within a very small fraction of a second but it may be prolonged by imposing a high resistance between the plate of tube $t_2$ and condenser c, so that the latter reaches the critical potential more slowly. For the purpose under consideration a maximum delay of nearly one second is obtained by putting in a total resistance of 125,000 ohms. This range is sufficient to enable drops to be photographed at any stage from the time before contact is made with the solid surface, through the process of impact and through the beginning of movement down the surface. A much longer delay is possible if desired.

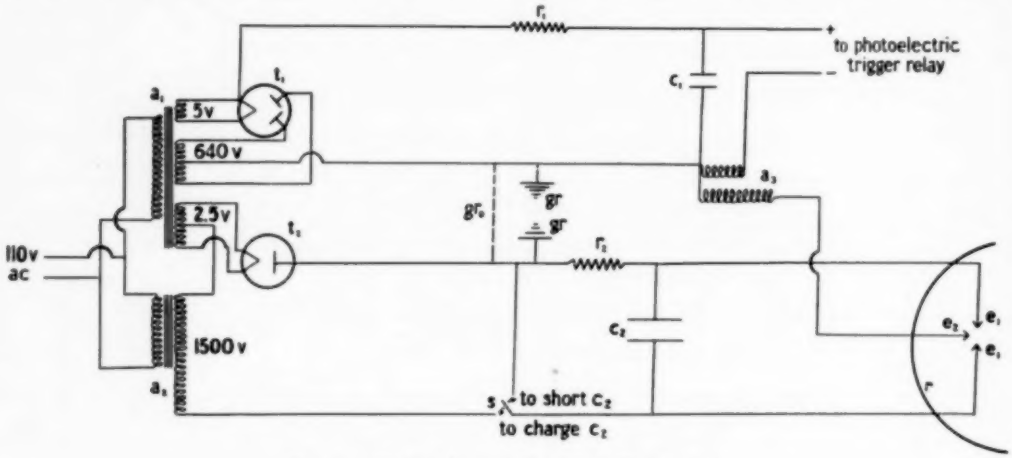



FIG. 2.—Wiring diagram for spark illuminator

| | | | |
|---|---|---|---|
| a, $a_2$ | Transformers | gr | Ground |
| $a_3$ | Spark Coil | r | Reflector |
| $c_1$ | 2 mfd. Condenser | $r_1$ | 100,000 ohm Resistor |
| $c_2$ | 25 mfd., 2,000 v. Condenser | $r_2$ | 10,000 ohm Resistor |
| $e_1$, $e_1$ | Mg Electrodes | s | Trip Switch |
| $e_2$ | Impulse Electrode | $t_1$ | Type 80 tube |
| $gr_0$ | Optional Ground for Movable Apparatus | $t_2$ | Type 866 tube |

Before another spark discharge is possible the reset switch must be opened to interrupt the current through tube $t_2$.

SURFACES AND LIQUIDS USED.—The method can be used with nearly any type of surface, but if the angle of contact is of interest, measurements are most readily made when the surface is a plane. The results to be mentioned below were obtained upon three artificial coatings applied to glass slides, one-half inch by three inches. The first was formed from the beeswax used in earlier studies on deposit. The slides were dipped into a one per cent solution of beeswax in carbon tetrachloride and allowed to drain and dry for approximately twenty-four hours before use. The second type of coating was made by dipping the slides into a 1:2 mixture of boiled linseed oil and paint thinner and allowing them to drain and then dry for about one month. The third kind of surface was made by dipping the slides into a light medium spray oil (viscosity 70 seconds Saybolt and unsulfonatable residue 90 per cent). These were used within five to ten minutes after withdrawing from the oil. The surface may be held at any angle but in the present work the coated slides were set upon a small board and held at a constant angle of approximately 37 degrees. The force with which the drop strikes may be controlled by altering the height from which it falls. This was three inches in all cases. The liquids used were (a) distilled water, (b) solutions of sodium oleate containing 71 mg. per gallon ($\frac{1}{4}$ ounce per 100 gallons) and 4,544 mg. per gallon (16 ounces per 100 gallons) and (c) solutions of Armour's grade A dried blood albumin of the same concentrations. A stock soap solution was made up at the concentration of 32 ounces per 100 gallons, and diluted as needed. The albumin solutions were made fresh each day.

The procedure for taking a picture of the impact of a drop was, briefly, as fol-

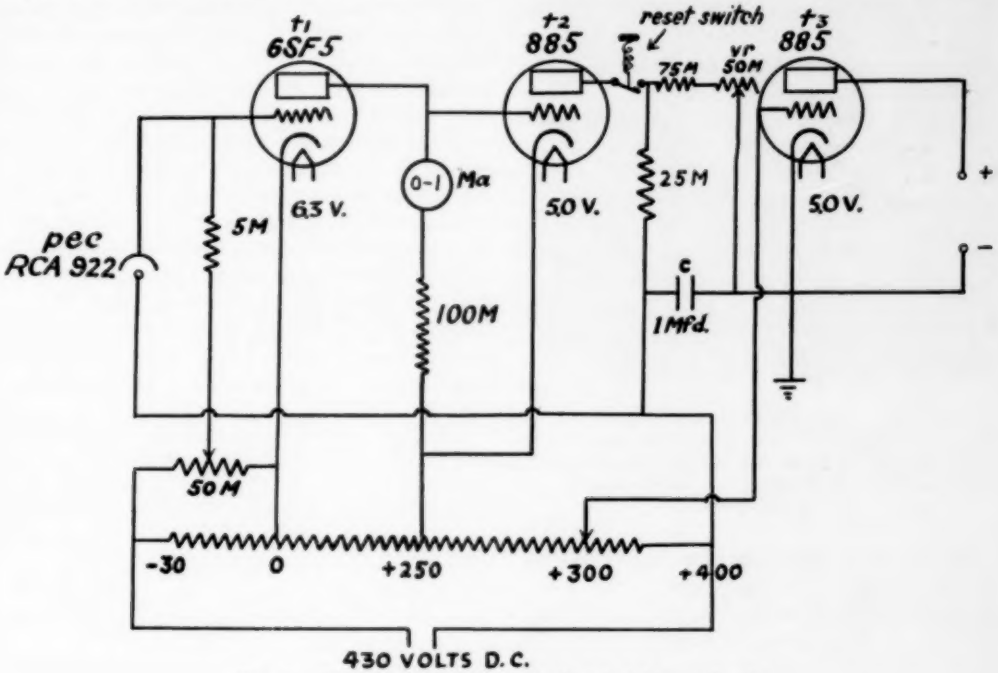
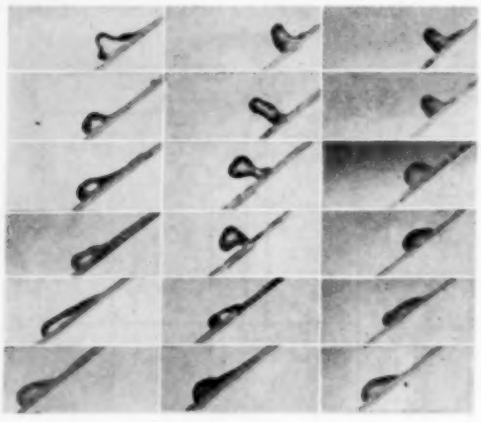



FIG. 3.—Wiring diagram of photoelectric trigger relay.*

| | |
|---|---|
| c | Condenser |
| ma | Milliameter |
| pec | Photoelectric Cell |
| $t_1$ | Amplifier Tube |
| $t_2$, $t_3$ | Thyratron Tubes |
| vr | Variable Resistor |

* Constructed by the Communications Supply Co., Moraga, Calif.

lows. With the liquid in the burette as shown in figure 1, a coated slide is placed in position and the variable resistor (vr in figure 3) set for the desired time delay. The reset switch is then closed, the shutter of the camera opened and the drop of liquid allowed to fall.



I II III

FIG. 4.—Behavior of drops of a dilute solution of blood albumin (¼ ounce per 100 gallons) upon different surfaces. I. Beeswax, II. Dried linseed oil, III. Spray oil.

RESULTS.—The most obvious variables in this work are the nature of the solid surface and the composition of the liquids striking it. The three columns of figure 4 show similar drops of the dilute blood albumin solution (71 mg. per gallon) upon the three surfaces. The photographs were taken of different drops after increasing time delays but a fresh surface was used each time so the series correspond to the behavior of a single drop upon each surface, photographed at successive times. Corresponding pictures in the three columns were taken at very nearly the same time after contact was first made with the surface. Successive positions accurately represent the distances moved along the slide. Since the advancing and receding angles of contact are of great theoretical and practical interest in the study of wetting and spreading, these pictures have been selected to show the behavior of the liquid after the drops start to move down the surface, rather than to illustrate the earlier stages of impact.

The advancing angles show no marked difference although this point can be decided quantitatively only by measurement of many drops. The receding angles show obvious differences. In the case of beeswax the receding angle very rapidly becomes small and a tail forms behind the drop. Numerous small droplets become detached and remain upon the surface. The rebound is very marked from the dried linseed oil surface and part of the drop almost becomes detached before it finally assumes the elongated shape shown in the last picture. The receding angle becomes small but finite and no droplets remain behind the tail. Upon the oil surface the drop of albumin solution never forms a very small receding angle of contact. On the basis of these pictures it is obvious that wetting decreases in the order beeswax, dried linseed oil, spray oil. The marked difference between the first and third surfaces is in agreement with the observation of Hoskins and Ben-Amotz (1938) that wetting by the aqueous phase of oil emulsions is greatly decreased as the surface becomes increasingly covered with oil.

Differences between various liquids are shown in figure 5 which includes pictures of water, a dilute and a concentrated solution of sodium oleate and a dilute and a concentrated solution of blood albumin, all upon a slide covered with oil. Picture 5a is included to show the preliminary flattening that occurs in practically the same manner immediately after contact is made by any of the liquids so far studied. The other drops shown in figure 5 are representative of the shapes assumed after motion down the surface is well started. It is obvious that the dilute soap solution forms approximately the same receding angle as pure water, whereas that of the dilute albumin solution is distinctly less. In the case of the concen-

FIG. 5.—Behavior of several liquids upon an oil surface. a—flattening of water immediately after impact; b—water; c—one-fourth ounce sodium oleate per 100 gallons; d—sixteen ounces sodium oleate per 100 gallons; e—one-fourth ounce blood albumin per 100 gallons; f—sixteen ounces blood albumin per 100 gallons.

trated solutions, sodium oleate forms a small but finite receding angle but that with blood albumin appears to approach zero very closely. This result is in agreement with the well known fact that protein solutions wet waxy and oily surfaces much better than do soap solutions.

It is perhaps worth emphasizing that, in contrast to most methods for measuring advancing and receding angles, the apparatus and procedure outlined in this report permit these important properties of sprays to be evaluated under dynamic conditions. Also, observations may be made either when the very first drop reaches a surface or after any desired volume of liquid has run over it. Thus changes in wetting and spreading under the influence of solutes which are adsorbed at the interface may be followed. Since small photographs may be taken very cheaply it is possible without excessive expense to make a record of many drops of any desired liquid upon any surface. Hence advantage may be taken of statistical methods for numerically evaluating and distinguishing between various liquid-solid systems.

SUMMARY.—An apparatus is described and figured for taking pictures, with very short exposure, of drops of a liquid at any desired time before, during or after contact with a solid surface. From the pictures, accurate measurements can be made of the advancing and receding angles. The effects of continued spraying may be studied by allowing any desired number of drops to strike and move down the surface. Since the method is relatively cheap it enables many tests to be made so that small differences in behavior may be evaluated with precision.

It is a pleasure to acknowledge the generous assistance given by Dr. Roderick Craig in designing and constructing the apparatus described in this report.

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# Toxicity of Hydrocyanic Acid to Eggs of Black Scale (*Saissetia oleae* (Bern.))[1]

A. F. SWAIN and R. P. BUCKNER

In the use of hydrocyanic acid as a fumigant for the control of insect pests, it has been generally considered that the eggs of insects are quite resistant. Where living plants are not concerned eggs of many species of insects can be killed by exposure to relatively high concentrations of hydrocyanic acid for periods of several hours. Where low concentrations or short exposure are necessary because of possible toxicity to plants, it has been presumed that eggs of insects will not be killed. In the fumigation of citrus this is a primary basis for recommendations as to the season in which to fumigate. Woglum (1912) stated that in the case of purple scale, *Lepidosaphes beckii* (Newm.), a dosage rate of three-fourths ounce[2] killed all the insects on leaves and twigs, but that double that dosage (1½-ounce rate) was required to kill the eggs. On fruit even a 1¾ ounce dosage rate was insufficient to kill the eggs. In the case of black scale, *Saissetia oleae* (Bern.), he stated that the full or 1 ounce dosage would destroy a large percentage of the eggs, but his recommendation as to time of treatment was; "Wait until the eggs of the old brood have all hatched, even if by this time some of the earliest issuing insects are becoming leathery." At present Woglum (1938) recognizes that the last few eggs to hatch are easier to kill than the scale insects themselves which may be several weeks old. With the exception of studies made by Woodworth (1915), no experimental data as to the toxicity of hydrocyanic acid vapors to eggs of black scale are available. He re-

[1] Contribution from the Entomological Laboratory of E. I. du Pont de Nemours & Co., Inc., The R. & H. Chemicals Department, El Monte, California.

[2] This refers to the amounts of sodium cyanide per unit in citrus fumigation as practiced at that time. The basic rate was one ounce per 100 cu. ft. for medium sized trees.

ported on a large series of laboratory fumigation experiments with eggs of scale insects, including those of black scale, and came to the conclusion that eggs were really very susceptible to hydrocyanic acid. However, neither concentrations of the gas nor lengths of exposure were stated, so definite data on these two points are lacking.

Due to the fact that most present recommendations for fumigation for control of the black scale on citrus in Southern California are based on the presumption that the eggs are highly resistant, the season for fumigation is very short. In fact, in some years, in the coastal districts there may be only three or four weeks available and in the interior districts only a couple of months. Because of these conditions it was decided to determine just what the toxicity of hydrocyanic acid vapor actually is to the eggs of black scale.

EXPERIMENTS.—The first experiments to determine this were made during the period from November 19, 1935 to January 10, 1936, using scale from Orange and Ventura Counties, where there are normally two generations a year. A second and larger series was carried on during the period from May 28 to July 9, 1936, using scale from three localities in Los Angeles County, viz., Whittier, North Whittier Heights and San Dimas. These represented both single-brood (North Whittier Heights and San Dimas) and double-brood scale (Whittier), as well as "resistant" scale (San Dimas), "semi-resistant" scale (North Whittier Heights) and "normal" scale (Whittier).[3]

The same technique was followed in all cases and is here briefly described. Twigs from citrus trees, usually oranges, bearing mature, egg-laying black scale females were brought into the laboratory and exposed for 45 minutes to hydrocyanic acid vapors in the laboratory fumatorium. Following this fumigation the twigs were placed in an HCN-free atmosphere until the next day when the eggs from several females were removed and placed in salve boxes, 50 mm. in diameter and 15 mm. in depth. With each series of fumigations, eggs from females not fumigated were kept as checks. The boxes of eggs were held in a constant temperature room (22° C.) until hatching was completed. Every day or two the eggs in each box were examined under a binocular microscope and all emerged nymphs removed and the number recorded.

Fumigation was carried out in a fumatorium of 340 liters capacity to which was connected a vacuum pump that withdrew the HCN-air mixture at a rate approximately equivalent to the rate of leakage of HCN-air mixture through a fumigation tent as used in the field. This equipment and its operation has been described previously by Pratt, *et al.* (1931). The actual concentration curve is represented by the equation $y = ae^{-.07x}$, where $y$ is the concentration in percent HCN in air by weight, $a$ the initial concentration, and $x$ the minutes exposure. The hydrocyanic acid was introduced into the fumatorium as a warm vapor, and at regular intervals analyses of the HCN-air mixture were taken. In each series of experiments four tests were made, with mean average concentrations of approximately 0.070, 0.080, 0.090, and 0.100 per cent HCN in air by weight. These concentrations are equivalent to those obtained in commercial fumigation of citrus trees by the 14 cc, 16 cc., 18 cc., and 20 cc. schedules.

RESULTS.—A study of the results of the first group of tests shows that HCN is highly toxic to the eggs of the black scale, that the higher the concentration of HCN the greater the toxicity, and that the more completely developed the embryo in the egg the more susceptible it is to HCN.

**Table 1.—Showing per cent black scale eggs hatched following fumigation at various concentrations, November 1935–January 1936. Six experiments. 45 minute exposure to decreasing concentration of HCN.**

| HCN CONCENTRATION[1] | None | 0.070 | 0.080 | 0.089 | 0.100 |
|---|---|---|---|---|---|
| DATE FUMIGATED | PER CENT EGGS HATCHED | | | | |
| November 19 | 70.2 | 31.3 | 37.3 | 6.2 | 0.14 |
| November 21 | 78.6 | 43.1 | 24.1 | 1.3 | 0.25 |
| November 29 | 89.1 | 32.3 | 0.73 | 0.43 | 0 |
| December 22 | 96.3 | 68.2 | 23.5 | 0 | 0 |
| January 3 | 70.6 | 72.6 | 39.5 | 0 | 0 |
| January 10 | 86.5 | 56.9 | 0 | 0 | 0 |
| Total | 81.6 | 50.5 | 21.6 | 1.7 | 0.08 |

[1] Concentration is expressed as per cent HCN in air by weight.

[3] The terms "resistant" and "normal" scale are in common usage in reference to scale insects attacking citrus in California and refer to their relative susceptibility to standard HCN fumigation. There have been many publications regarding "resistant" scale, to which it is unnecessary to refer here. A general resume of this subject is presented in "Insects of Citrus and other Sub-tropical Fruits" by H. J. Quayle, Comstock Publ. Co., Ithaca, 1938, pp. 489–94.

These are shown in table 1, in which are given the total per cent eggs hatched for each experiment, and in figure 1*a*, in which the accumulated per cent eggs hatched is plotted over the number of days following fumigation.

Hatching began as early as 6 days after fumigation with the lower concentrations of gas, but it was 31 days before hatching commenced after fumigation with the highest concentration. By the method of analysis of variance (table 2) the data show the highly significant effect of the concentration of HCN in prevention of egg hatching, but they fail to reveal any effect of date of treatment. However, a study of the individual tests indicate that although some eggs hatched following exposure to all four concentrations during early November, from November 29 on none hatched at the highest concentration, by December 22 none at the next highest concentration and by January 10 none except at the lowest concentration. As will be shown later, date of treatment of summer brood eggs has a highly significant effect on results (table 4). There are two complicating factors that have a bearing on this seeming discrepancy. The first is that in the winter the hatching period is more uneven and extends over a longer period than in the summer; hence the expectation of the date of treatment within the period covered by these experiments having an effect on results is much lower. The second factor is that the scale used in these winter experiments was from two widely separated localities, the scale for the first three series being from Orange County and that for the last three from Ventura County.

**Table 2.—Analysis of variance of per cent black scale eggs hatching after exposure to four concentrations of HCN of six dates in 24 experiments from November 1935 to January 1936.**

| SOURCE OF VARIATION | DEGREES OF FREEDOM | SUM OF SQUARES[1] | MEAN SQUARE |
|---|---|---|---|
| Total | 23 | 9,723.27 | — |
| Dates of treatment | 5 | 616.43 | 123.3 |
| Concentration HCN | 3 | 7,597.76 | 2,532.6[2] |
| Error | 15 | 1,509.08 | 100.6 |

[1] Percentages have been transferred to angles for purposes of calculations, as suggested by Bliss (Ohio Journ. Science **38** (1): 9–12, 1938).
[2] Highly significant; F=25.17, surpassing the 1 per cent point, 5.42, for 3 and 15 *df*.

During the period from May to July, 1936, a much larger series of similar experiments was run. In this series there were ten experiments, one each week, each including four concentrations of HCN and scale from three sources. As already stated these three sources included single- and double-brood scale, and "resistant," "semi-resistant," and "normal" scale. In figure 1*b*, are shown the average accumulated per cents of eggs hatched for the complete series. In comparing results as shown in figure 1*a* and *b*, the most noticeable point is the much greater susceptibility of the summer eggs to HCN than of the winter eggs. In table 3 are shown the total per cents of eggs hatched in each experiment. In the last three series of tests, June 26, July 3 and July 9, no eggs hatched whatsoever although an average of 89.4 per cent hatched in the check lots for these three tests.

**Table 3.—Showing per cent black scale eggs hatched following fumigation at various concentrations, May to July 1936. Ten experiments with scale from three localities. 45 minute exposure to decreasing concentrations of HCN.**

| HCN CONC.[1] | None | | | 0.069 | | | 0.080 | | | 0.089 | | | 0.101 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SOURCE[2] LOCALITIES | A | B | C | A | B | C | A | B | C | A | B | C | A | B | C |
| DATE FUM. | PER CENT EGGS HATCHED | | | | | | | | | | | | | | |
| May 7 | 89.4 | 87.6 | — | 19.9 | 1.4 | — | 0.8 | 3.9 | — | 0 | 0 | — | 0 | 0 | — |
| May 15 | 97.5 | 92.7 | — | 1.4 | 23.2 | — | 1.4 | 0 | — | 1.9 | 0 | — | 0 | 0 | — |
| May 21 | 99.7 | 86.8 | — | 4.4 | 6.4 | — | 3.0 | 7.2 | — | 3.7 | 2.6 | — | 0 | 0 | — |
| May 28 | 99.4 | 96.3 | 98.3 | 2.7 | 23.7 | 26.4 | 4.8 | 3.0 | 1.8 | 0.4 | 1.6 | 0.4 | 0 | 0 | 0 |
| June 4 | 98.6 | 61.9 | 98.8 | 21.3 | 5.2 | 15.2 | 16.7 | 0.2 | 15.5 | 0.9 | 1.8 | 0 | 7.8 | 4.7 | 0 |
| June 10 | 96.8 | 90.7 | 97.1 | 15.8 | 15.1 | 8.5 | 6.2 | 4.1 | 1.7 | 0 | 0 | 0 | 0 | 0 | 0 |
| June 18 | 98.9 | 88.0 | 98.6 | 0 | 11.7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| June 26 | 98.9 | 96.8 | 85.9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| July 3 | 98.5 | 90.7 | 93.1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| July 9 | — | 81.1 | 79.8 | — | 0 | 0 | — | 0 | 0 | — | 0 | 0 | — | 0 | 0 |
| Total | 98.1 | 88.1 | 90.1 | 7.5 | 8.6 | 7.6 | 2.8 | 2.2 | 2.9 | 2.1 | 0.7 | 0.1 | 0.9 | 0.6 | 0 |

[1] Concentration is expressed as per cent HCN in air by weight.
[2] A refers to Whittier, B to North Whittier Heights and C to San Dimas as localities from which scale were obtained.

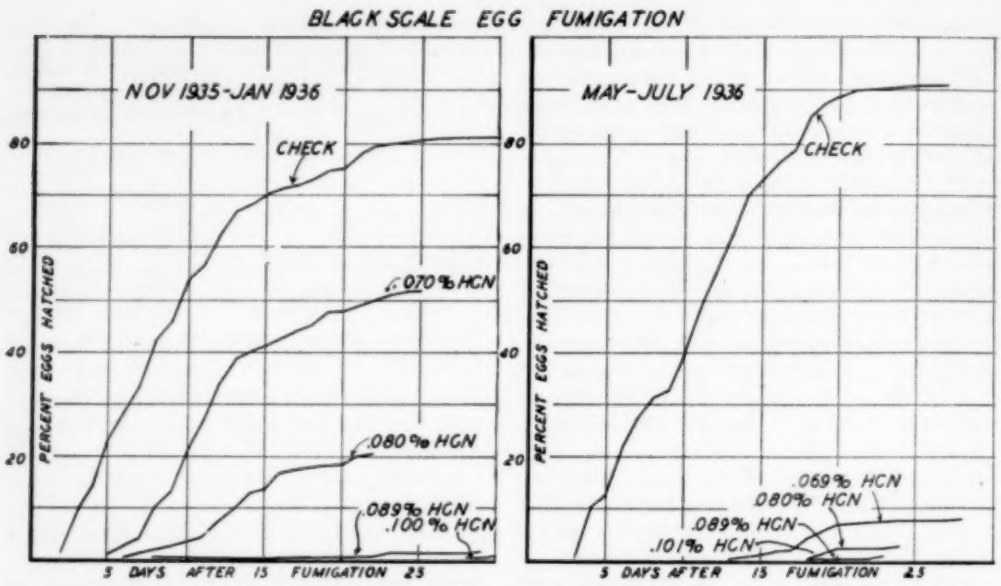


FIG. 1.—Showing accumulated per cent black scale eggs hatched following fumigation with HCN at various concentrations. *a* (left) Winter Brood 1935–36, *b* (right) summer brood 1936 (average of scale from three localities).

This indicates the great susceptibility of eggs to HCN when the embryos are practically fully developed. Furthermore, no eggs hatched when exposed to the two higher concentrations after June 4; to the next to the lowest concentration after June 10; and to the lowest concentration after June 18.

**Table 4.—Analysis of variance of per cent black scale eggs hatching after exposure to four concentrations of HCN on five dates from May 28 to June 26, 1936 incl. Sixty experiments with scale from three sources.**

| SOURCE OF VARIANCE | DEGREES OF FREEDOM | SUM OF[1] SQUARES | MEAN SQUARE |
|---|---|---|---|
| Total | 59 | 5,186.71 | — |
| Individual lots (error) | 40 | 1,334.99 | 33.4 |
| Dates of treatments | 4 | 1,604.02 | 401.0[2] |
| Concentrations of HCN | 3 | 1,491.07 | 497.0[3] |
| Stock (Source of scale) | 2 | 35.15 | 17.6 |
| Discrepancy | 10 | 721.48 | 72.1 |

[1] Percentages have been transferred to angles for purposes of calculations, as suggested by Bliss (l. c.).
[2] Highly significant; F = 12.01, surpassing 1 per cent point, 3.83, for 4 and 40 *df*.
[3] Highly significant; F = 14.88, surpassing 1 per cent point, 4.31, for 3 and 40 *df*.

Unfortunately, eggs from the San Dimas area were not included until the test of May 28, but a comparison of results of the five tests in which eggs from all three sources of supply are included and in all of which, except the last, some hatched, is shown in table 4.

This analysis of variance shows clearly the significance of both HCN concentration and of date of treatment on egg hatching, verifying results of the winter series of experiments. The nearer to the normal hatching period the greater is the mortality. In no case did any eggs hatch, following fumigation, in less than thirteen days. The earliest hatchings following treatment at different concentrations are noted in table 5. This shows a secondary effect on the eggs of exposure to HCN, viz., that the greater the concentration, the earlier in the developmental stage the embryo is killed.

An outstanding and unexpected result brought out in these experiments is the fact that there is no difference in susceptibility of the eggs of black scale traceable to the source locality or, in other words, to "resistance" of the scale insects themselves. Scale from San Dimas is well known to be much more tolerant to HCN

**Table 5.—Days following fumigation on which egg hatching commenced May–July, 1936.**

| PER CENT HCN CONCENTRATION | RANGE | AVERAGE |
|---|---|---|
| .069 | 13–21 | 16.7± .66[1] |
| .080 | 16–24 | 19.6± .48 |
| .089 | 19–27 | 21.1± .78 |
| .101 | 18 | 18[2] |

[1] Standard deviation.
[2] Eggs hatched in only one test at this concentration.

than scale from Whittier, the former being typical "resistant" and the latter "normal" or non-resistant scale. Scale from North Whittier Heights ranges between that from the other two localities, being much more resistant than scale from Whittier, but less so than scale from San Dimas. Apparently this phenomenon of "resistance" is not present in the eggs.

As a field check, a few lemon trees in the grove at San Dimas from which the scale for the laboratory experiments was obtained, were fumigated. Six trees were fumigated on the evening of June 2, three at the 14 cc. schedule and three at the 18 cc. schedule. Similar groups were fumigated on June 11, June 23 and July 7. On the day following each fumigation, scales were brought into the laboratory, the eggs removed and placed in salve boxes in the constant temperature room, and examined periodically, as were those fumigated in the laboratory. In table 6 are shown the total per cents of eggs hatching in each of these tests.

Although accurate data were impossible to obtain, it was estimated that, at the dates of fumigation, approximately 50, 60, 70 and 80 per cent, respectively, of the eggs were already hatched. Results as shown in table 6 check quite closely with those obtained in the laboratory experiments, where the last fumigation that permitted any eggs to hatch from the San Dimas stock (C in table 3) was on June 10, at a concentration approximately equivalent to that obtained with the 14 cc., dosage, and on June 4, with the 18 cc. dosage.

CONCLUSIONS.—The experiments reported here show that hydrocyanic acid vapor is highly toxic to the eggs of black scale at short exposures and in concentrations suitable for fumigation of citrus trees. The winter eggs are less susceptible than the summer eggs, but fortunately much higher concentrations of HCN can be used in winter fumigation than in summer. The minimum normal dosage for winter fumigation is 20 cc. per unit which is equivalent to the maximum concentration used in these experiments. The normal summer dosages are 16 cc. and 18 cc. per unit, which are equivalent to the .080 and .090 per cent HCN concentrations used. At these concentrations no eggs hatched in any of the experiments after June 4, which was six or seven weeks earlier than commercial fumigation started in any of the localities from which eggs for these experiments were obtained.

The fact that the difference in susceptibility to HCN of black scale from different localities is not carried over into the eggs and the further evidence of the high toxicity to the eggs of HCN at concentrations usable in field fumigation indicate that satisfactory control of "resistant" black scale might be secured by earlier season fumigation.

**Table 6.—Showing per cent black scale eggs hatched following fumigation of lemon trees at San Dimas during June–July 1936. Four Experiments at two dosages.**

| HCN DOSAGE | 14 cc. | 18 cc. |
|---|---|---|
| DATE FUMIGATED | PER CENT EGGS HATCHED | |
| June 2 | 40.4 | 0 |
| June 11 | 3.2 | 0 |
| June 23 | 2.0 | 0 |
| July 7 | 0 | 0 |
| Average | 22.8 | 0 |

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UNDER a revision, on September 20, 1939, of the Idaho quarantine (No. 20) relating to the tomato pinworm, tomatoes and tomato plants will be accepted from infested regions if certified as having originated in an area known to be free from the worm, or as having been fumigated according to specifications.

# Small Plots in Field Experiments on Hop Pests

H. E. Morrison, *Assistant in Entomology, Oregon Agricultural Experiment Station*

Hop growing is one of the leading agricultural pursuits of the State of Oregon and more than 21,000 acres are devoted to this enterprise. The crop is subject to the attack of many pests, the more important of which are the common red spider, *Tetranychus telarius* Linn., and the hop aphid, *Phorodon humuli* Schrank.

In 1937, at the urgent request of Oregon hop growers, the Oregon Agricultural Experiment Station undertook investigations of many problems affecting the hop industry. Fourteen acres of hops were planted during 1937 and 1938 on the Oregon Agricultural Experiment Farm at Corvallis. One-half acre was made available to the Department of Entomology, in 1938, for field trials. This was planted to the late cluster variety, and consisted of mature (two year old) plants interspersed to some extent with baby (one year old) plants.

The subject of hop field experimental technique, for the most part, is largely lacking in the literature; therefore the department was confronted with the problem of developing a suitable experimental method. The hop aphid was not present in sufficient numbers to furnish good experimental data; hence this paper is confined to data on the red spider for the 1938 season.

The experimental block was divided into seven equal plots, each of which was subdivided into eight equal plats. Each plat was considered as representative of its plot and included six hop plants, regardless of age or sex. Treatments were assigned to the plats by strict random distribution and appeared but once in each plot. Thus the treatments were accordingly replicated as many times as there were plots, which in this instance was seven. The diagram of the experimental block is shown below.

This experimental method was subjected to different tests in order to determine its feasibility. Records of each plant in the experimental block were taken every 10 days and the average numbers of red spiders per leaf (a measure of population density) as well as the percentage of leaves infested (a measure of population distribution) were recorded, by plats. The population data (density and distribution), by plats, just prior to spray applications are given as follows:

Populations of **Tetranychus telarius** in spray block, East Farm, Corvallis, Ore. July 29, 1938.

**Table 1.—Number of red spiders per leaf prior to spray applications.**

| Treatment No. | Replications | | | | | | | Mean |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
| 1 | 6 | 1 | 0 | 3 | 3 | 3 | 4 | 3 |
| 2 | 3 | 4 | 3 | 3 | 4 | 7 | 9 | 5 |
| 3 | 7 | 11 | 1 | 3 | 2 | 1 | 17 | 6 |
| 4 | 1 | 7 | 0 | 0 | 6 | 1 | 3 | 3 |
| 5 | 1 | 1 | 0 | 1 | 1 | 12 | 3 | 3 |
| 6 | 9 | 14 | 1 | 1 | 1 | 2 | 87 | 16 |
| 7 | 7 | 1 | 6 | 2 | 5 | 2 | 2 | 4 |
| 8 | 3 | 0 | 6 | 9 | 11 | 1 | 1 | 4 |

Differences necessary for significance at 19–1 odds = 14.

Populations of **Tetranychus telarius** in spray block, East Farm, Corvallis, Ore. July 29, 1938.

**Table 2.—Percentage of leaves infested with red spider prior to spray applications.**

| Treatment No. | Replications | | | | | | | Mean |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
| 1 | 15 | 4 | 0 | 13 | 5 | 12 | 20 | 10 |
| 2 | 7 | 8 | 12 | 10 | 10 | 17 | 16 | 11 |
| 3 | 15 | 17 | 2 | 8 | 7 | 7 | 28 | 12 |
| 4 | 2 | 17 | 0 | 0 | 15 | 3 | 15 | 7 |
| 5 | 2 | 4 | 0 | 2 | 2 | 25 | 10 | 6 |
| 6 | 20 | 17 | 5 | 5 | 2 | 8 | 30 | 12 |
| 7 | 12 | 12 | 14 | 3 | 13 | 8 | 7 | 10 |
| 8 | 5 | 0 | 12 | 13 | 22 | 5 | 2 | 8 |

Differences necessary for significance at 19–1 odds = 9.

It was assumed that any differences in the mean of these data would indicate that this system of field experimentation was not satisfactory because no factors were introduced to produce such differences. The two sets of data were subjected to statistical analysis and no differences were found between the means at odds of 19 to 1. Accordingly it was concluded that this system of field experimentation was satisfactory.

These data indicate that seven replications of treatments are necessary in hop field experimentation on *T. telarius* Linn. This requirement would have limited the number of possible treatments to four if the experimental block had been divided into plats by rows. Eight treat-

**Fig. 1.—Diagram of experimental spray block.**

| PLANT NOS. | PLOT 1 | | PLOT 2 | | PLOT 3 | | PLOT 4 | | PLOT 5 | | PLOT 6 | | PLOT 7 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12 | 5 5 | 7 7 | 3 3 | 8 8 | 5 5 | 1 1 | 2 2 | 3 3 | 7 7 | 4 4 | 1 1 | 6 6 | 2 2 | 4 4 |
| 11 | 5 5 | 7 7 | 3 3 | 8 8 | 5 5 | 1 1 | 2 2 | 3 3 | 7 7 | 4 4 | 1 1 | 6 6 | 2 2 | 4 4 |
| 10 | 5 5 | 7 7 | 3 3 | 8 8 | 5 5 | 1 1 | 2 2 | 3 3 | 7 7 | 4 4 | 1 1 | 6 6 | 2 2 | 4 4 |
| 9 | 6 6 | 2 2 | 6 6 | 7 7 | 4 4 | 3 3 | 1 1 | 8 8 | 8 8 | 3 3 | 5 5 | 8 8 | 7 7 | 1 1 |
| 8 | 6 6 | 2 2 | 6 6 | 7 7 | 4 4 | 3 3 | 1 1 | 8 8 | 8 8 | 3 3 | 5 5 | 8 8 | 7 7 | 1 1 |
| 7 | 6 6 | 2 2 | 6 6 | 7 7 | 4 4 | 3 3 | 1 1 | 8 8 | 8 8 | 3 3 | 5 5 | 8 8 | 7 7 | 1 1 |
| 6 | 4 4 | 8 8 | 2 2 | 1 1 | 6 6 | 7 7 | 5 5 | 4 4 | 2 2 | 6 6 | 7 7 | 3 3 | 5 5 | 3 3 |
| 5 | 4 4 | 8 8 | 2 2 | 1 1 | 6 6 | 7 7 | 5 5 | 4 4 | 2 2 | 6 6 | 7 7 | 3 3 | 5 5 | 3 3 |
| 4 | 4 4 | 8 8 | 2 2 | 1 1 | 6 6 | 7 7 | 5 5 | 4 4 | 2 2 | 6 6 | 7 7 | 3 3 | 5 5 | 3 3 |
| 3 | 3 3 | 1 1 | 5 5 | 4 4 | 2 2 | 8 8 | 6 6 | 7 7 | 5 5 | 1 1 | 4 4 | 2 2 | 8 8 | 6 6 |
| 2 | 3 3 | 1 1 | 5 5 | 4 4 | 2 2 | 8 8 | 6 6 | 7 7 | 5 5 | 1 1 | 4 4 | 2 2 | 8 8 | 6 6 |
| 1 | 3 3 | 1 1 | 5 5 | 4 4 | 2 2 | 8 8 | 6 6 | 7 7 | 5 5 | 1 1 | 4 4 | 2 2 | 8 8 | 6 6 |
| ROW NOS. | 71 72 | 73 74 | 75 76 | 77 78 | 79 80 | 81 82 | 83 84 | 85 86 | 87 88 | 89 90 | 91 92 | 93 94 | 95 96 | 97 98 |

ments were made possible by the employment of the small plat system of experimentation.

The increased difficulties in the mechanics of spray application in small plats was overcome to a large extent by carefully planning routine operations and by preparing proper proportions of toxic materials prior to application. Wind and strong air currents greatly hindered spraying during mid-day. This problem was reduced to a minimum by applying the sprays between 4:00 A.M. and 7:00 A.M. This allotted time has proven more than enough to complete the task of spraying one-half acre of hops.

# A Note on the Frequency Distribution of Black Scale Insects*†

WM. M. UPHOLT and RODERICK CRAIG

In many cases of insect population distribution studies the statistical methods now in use by entomologists may be applicable, but there are others which cannot be adequately covered by these methods. The primary reason for this is not lack of diligence on the part of mathematicians but rather the failure of the entomologist to appreciate the statistical mode of attack and to furnish the statistician with sufficient biological facts. In setting up a statistical method, certain assumptions must be made about the distribution of the organisms concerned. Given the distribution and the significant biological factors affecting it, the problem becomes one of mathematics. The determination of the distribution and the factors affecting it is primarily the function of the biologist.

Of all the conceivable types of distributions of organisms, only three have been used to formulate agricultural statistical treatments—the binomial, the normal and the Poisson. Until the organism being studied has been shown to have a distribution similar to one of these, the methods based upon them cannot properly be used. The point of attack, therefore, is to establish the distribution for the particular organism being studied. This is usually done by sampling a population from a uniform region, that is, a region in which the ecological factors are as nearly uniform as possible. The sampling units consist of one or more units from the region containing the organism. The unit is the smallest typical portion of the biologically significant region. Thus in the case of the black scale only the portions of the trees inhabited need be considered as parts of the biologically significant region; a leaf and the adjacent twig constitutes a unit. Many sampling units must be chosen at random from this region and the number of scale insects per unit counted. In any case each tree in an orchard may be a region or may consist of several regions. The units are

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† The writers are indebted to Mr. E. M. Chavaud of Röhm and Haas Co. for suggesting this problem.

then arranged according to the number of organisms each contains. This data can be compared with the expected values on the basis of any given theoretical distribution.

The distribution of some counts of black scale populations on oranges was determined. In this study the sampling unit consisted of ten adjacent leaves and the stem to which they were attached. The number of sampling units containing various numbers of scale insects is given in table 1. The third column gives the expected distribution assuming it to be of the Poisson type. It is evident that the actual distribution was of a very different kind. The fourth column gives the expected distribution calculated on the basis of the type C "contagious" distribution of Neyman (1939). The contagious distribution was designed to fit the idealized population distribution of the European corn borer larvae from the data of Beall (in Neyman's paper). It is again evident that the scale population does not conform to this contagious distribution. The normal and binomial distributions do not apply to this type of discrete data.

**Table 1.—Comparison of observed frequency distribution of 821 unit-samples of black scale with that theoretically expected on basis of (A) Poisson distribution, and (B) type C, "contagious" distribution.**

| Number of Scales per Unit sample | Number of Unit-Samples | | | | | |
|---|---|---|---|---|---|---|
| | Observed Frequency | | Expected Poisson Distribution | | Expected Contagious Distribution (Type C) | |
| 0 | 199 | | 3.2 | | 497.1 | |
| 1 | 124 | | 17.6 | | 16.0 | |
| 2 | 106 | | 49.0 | | 8.0 | |
| 3 | 65 | | 90.7 | | 5.2 | |
| 4 | 42 | | 126.0 | | 3.8 | |
| 5 | 46 | | 140.0 | | | |
| 6 | 36 | | 130.0 | | | |
| 7 | 30 | 285 | 103.0 | 534.5 | | 290.9 |
| 8 | 14 | | 71.4 | | | |
| over 8 | 159 | | 90.1 | | | |

First moment about zero = 5.5556. Second moment about the mean = 92.126.

Professor Neyman very kindly pointed out that his type of contagious distribution should not be expected to fit since the biologies of the two insects are so different. While it is true that the population of scale insects arises from a number of centers, i.e., the female scales, and the populations of corn borer larvae arise from clusters of eggs, the origins of these distribution centers are not the same. The population distribution of the adult female scale insects is not a random one, whereas the Neyman type of contagious distribution assumes that the egg masses of the corn borer are deposited at random by the females. The peculiarity of the scale insect population is that the distribution of any one generation is dependent upon the distribution of the previous generation as well as upon many environmental factors. It should be emphasized that the black scale population does follow some type of contagious distribution. The crucial point of a contagious distribution is that the presence of one organism within a given region increases the chance that more organisms will be found there. This is exactly the situation in this case since the presence of a scale insect implies that the center of distribution is near and that more scale insects would be expected in the immmediate vicinity.

Obviously the failure of black scale populations to conform to the Neyman type of contagious distribution is no reflection upon the theory which is probably applicable to many insects similar to the European corn borer. The failure is a warning to entomologists to make certain that the biology of the insect being studied conforms sufficiently closely to that anticipated by the theoretical distribution to be used. It is also evident, as a little consideration of known insect biologies will convince one, that many insect population distributions will probably not conform to any of the four types of theoretical distributions mentioned in this note. Entomologists must learn what the actual distributions of insect populations are and how they are affected by environmental factors before the appropriate statistical methods can be developed.

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# Flight Habits and Seasonal Abundance of Dried-Fruit Insects

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INTRODUCTION.—A study of the flight habits and seasonal abundance of certain insects which infest stored raisins was undertaken during the summer of 1938 in a raisin-storage yard at Fresno, Calif. A rotary net of the type developed by F. R. Lawson and J. C. Chamberlin, of the Bureau, for use in investigations on sugar-beet insects was used for this work.

In the course of the work data on the flight habits and seasonal abundance of the following species or groups of insects were obtained: raisin moth (*Ephestia ſgulilella* Greg.); tobacco moth (*E. elutella* (Hbn.)); Mediterranean flour moth (*E. kuehniella* Zell.); *Ephestiodes nigrella* Hulst; Indian-meal moth (*Plodia interpunctella* (Hbn.)), lead cable borer (*Scobicia declivis* (Lec.)); dried fruit beetle (*Carpophilus hemipterus* (L.)); foreign grain beetle (*Ahasverus advena* (Waltl)), *Cryptophagus* sp.; hairy fungus beetle (*Typhaea stercorea* (L.)); *Laemophloeus* sp.; dermestids; the red flour beetle (*Tribolium castaneum* (Hbst.)); and the saw-toothed grain beetle (*Oryzaephilus surinamensis* (L.)). Some information was secured on several other species. These insects fall naturally into three classes, those that fly during the day, those that fly at night, and those that are chiefly crepuscular in flight.

APPARATUS AND PROCEDURE.—The net consisted of a wire-cloth cone, about 19 inches in diameter at the larger end and 3 inches at the smaller and 53 inches long, attached to a 12-foot counterbalanced boom. Tied to the smaller end of the net was a removable cloth bag to receive the insects. The net was driven by a one-half horsepower electric motor, directly connected to a worm gear, which rotated the net at 50 revolutions per minute.

The net was in continuous operation, except for a few days, from April 14 to October 31. Each morning the insects were collected and separated into Microlepidoptera, storage beetles, and discards; those in the first two groups were identified. On account of the large amount of material to be examined, the total numbers of most insects were estimated by sampling. In addition to the daily totals, flight records were made at 15-minute intervals on 10 days to determine the factors associated with the flight of different species. Five of the series of short-interval observations were concerned with day-flying forms and five with species that fly chiefly in the evening and night. Temperature, relative humidity, and light intensity (when less than 1,000 foot-candles) were recorded at the end of each 15-minute interval.

DAY-FLYING INSECTS.—The nitidulids and dermestids were the only insects recorded that flew abundantly during the daylight hours (fig. 1). They did not fly at night. These totaled 291,000 individuals and composed 77 per cent of the beetles that were separated from the catches.

During the season 96 per cent of the nitidulids were dried fruit beetles. These were already active when operation of the net was begun in April and the numbers taken increased from 59 per day during that month to 1,795 and 1,933 per day in May and June. The largest number taken in a single day was 4,399, on May 13. Decrease in numbers began in July and continued through the season.

Study of the flight habits of the dried fruit beetle, by means of the short-interval observations, showed that flight did not start until full daylight and until after the temperature reached 65 degrees F. During the morning there was usually a steady increase in activity as the temperature rose. On certain days a period of depression was noted during the middle of the day, followed by increased activity late in the afternoon. Although the midday depression began when the temperature reached about 100 degrees, the increase late in the afternoon started when the temperature was still 100 degrees. It is evident that this depression was not associated with temperature alone, but the factors involved are not understood. Flight ceased with the coming of darkness.

The presence of 125,000 dermestid beetles among the insects taken by the net seems to be associated with the fact that heavy infestations of insects which

attack raisins in storage produce much insect debris, such as molted skins, pupal cases, and dead insects. The group has not been identified to species, but most of the individuals apparently belonged to the genus *Trogoderma*. The dermestids were most active during the warmer months of the summer. On an average 14 per day were taken in April, 47 in May, 127 in June, and 651 in July. In August the average was 2,098 per day. The largest number taken in a single day was 4,019 on August 22.

Information obtained on the daily flight habits of the dermestids showed that flight began after it was full daylight and after the temperature had reached 75 degrees. As in the case of the dried fruit beetle, flight activity of dermestids increased with temperature and ceased at sundown, but apparently was less influenced by high temperatures.

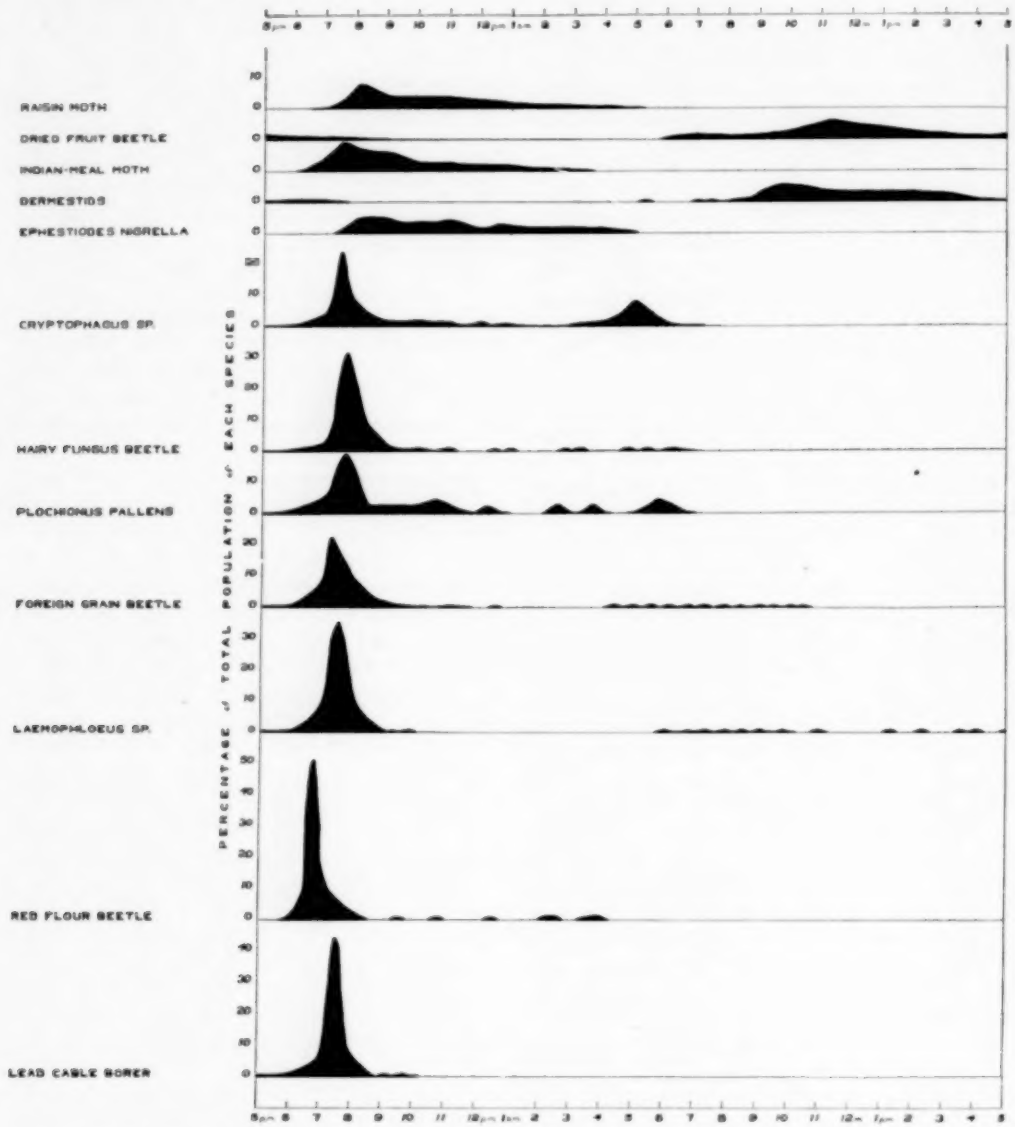


FIG 1.—Daily flight activity of various dried fruit insects, somewhat generalized. These patterns of flight appear to be typical of warm-weather activity.

NIGHT-FLYING INSECTS.—The five species of Microlepidoptera listed composed the group of insects which flew during the night (fig. 1).

The raisin moth, of which there were 246,844 individuals, represented 79 per cent of the moths and 36 per cent of the insects recorded; the average taken per night was 1,292. There was a limited flight during the last half of April, when 29 per night were taken. In May the numbers increased steadily and the period of greatest abundance occurred from May 31 to June 8, when an average of 4,500 per night were taken. Between June 9 and July 25 the nightly catches decreased slowly but the average remained above 2,000. About 500 per night were recorded between July 26 and the end of the season. During the season 29 per cent of the moths examined were females, the percentages fluctuating between 22 and 35. Fifty-three per cent of the females carried eggs. The percentage increased from 16 in May to 94 in October.

Nightly flight of the raisin moth began about a half hour after sunset and continued until sunrise unless stopped by low temperature. The sexes were present in the air in about equal numbers early in the night but later the males greatly outnumbered the females. Flight did not occur at a temperature below 55 degrees, it was very limited between 55 and 60 degrees, and little took place on warm nights after the temperature dropped to 65 degrees.

The Indian-meal moth was the second in abundance; 248 per night were taken. Beginning April 20, moths were captured nearly every night until the end of October. Three overlapping broods were indicated with peaks about 65 days apart. As with the raisin moth the percentage of females observed was 29. The per cent of egg-carrying females ranged from 27 in April to 87 in October. The flight of this moth began at about the same time as that of the raisin moth, one-half hour after sunset, but ended at an earlier hour and at a higher temperature. Only 2 of the 589 moths recorded during short-interval observations were taken when the temperature was below 60 degrees.

*Ephestiodes nigrella* Hulst occurs in stored dried fruit but its importance has not been determined. The total number captured was 12,305, or 64 per night. The moth was active when the use of the net was begun in April, and during that month the average catch was 40 per night. May, when 209 per night were recorded, was the month of greatest abundance. The nightly flight habits were similar to those of the raisin moth.

The tobacco moth occurred in the storage sheds but was not plentiful there. It was represented in the net collections by 4,315 individuals during the season. The species was not active early in the spring, for none were recorded until May 10. July was the month of greatest abundance.

The Mediterranean flour moth was represented by 192 individuals; none were taken after June 18. The unusual thing about the record was that all specimens taken were males.

CREPUSCULAR INSECTS.—The balance of the beetles recorded exhibited a common characteristic in that their most active period of flight occurred near or soon after sunset. This group includes the hairy fungus beetle, foreign grain beetle, *Laemophloeus* sp., *Cryptophagus* sp., red flour beetle, lead cable borer, and, probably, the saw-toothed grain beetle.

The hairy fungus beetle, a cosmopolitan insect which infests stored grain and seeds, tobacco, and cacao, is common in raisin storages. Its daily aerial activity as shown by the catches in the net was very erratic, wide variations in abundance occurring from day to day. The largest abrupt change in the population in the air took place in June, when 4 were recorded on the 20th and 3,523 on the following day. May was the month of greatest activity of this beetle. Study of the diurnal movements showed that flight occurred at practically all hours. In warm weather, however, the period of most active flight began with sunset and lasted until about the end of twilight. In cool weather, evening activity began at an earlier hour. Flight was not recorded when the temperature was below 64 degrees.

The foreign grain beetle, commonly associated with moldy foodstuffs, is also found in the stored raisins. As in the case of the hairy fungus beetle, abrupt differences appeared in the numbers recorded from the net from day to day. May, when 312 per day were taken, was the month of greatest abundance. Al-

though this species is essentially a crepuscular flier, it was taken in small numbers at nearly all times of day when the temperature was above 65 degrees. The most active flight period began 10 to 30 minutes before sunset and lasted from one to two hours, ending shortly before complete darkness occurred.

The group *Laemophloeus* sp. probably consisted, for the most part, of the species *ferrugineus* (Steph.), which has been found associated with stored raisins. Unlike the hairy fungus beetle and the foreign grain beetle, it was most abundant in hot weather, July and August being when the temperature was below 61 degrees.

The red flour beetle is a minor pest in raisins. During the season 3,461 were taken, 0.9 per cent of the beetle collections. It was not found regularly in the catches until August 20. During the remainder of that month 30 per day were taken; in September the average was 100 and in October, 11. Data from the short-interval records show that active flight was confined to a period beginning at sunset and continuing into the early twilight when the temperature was above 75 degrees.

**Table 1.—Numbers of the different species of dried-fruit insects recorded from rotary net in 1938, Fresno, Calif.**

| INSECTS | April 14–30 | May | June | July | August | September | October | Total |
|---|---|---|---|---|---|---|---|---|
| MOTHS: | | | | | | | | |
| *Ephestia figulilella* | 457 | 42,122 | 90,481 | 48,861 | 29,276 | 14,093 | 15,552 | 246,844 |
| *Ephestia elutella* | 0 | 147 | 148 | 1,611 | 1,273 | 843 | 293 | 4,315 |
| *Ephestia kuehniella* | 6 | 76 | 10 | 0 | 0 | 0 | 0 | 92 |
| *Ephestiodes nigrella* | 633 | 6,473 | 2,850 | 1,569 | 454 | 257 | 69 | 12,305 |
| *Plodia interpunctella* | 41 | 3,039 | 3,043 | 11,055 | 11,247 | 11,690 | 7,215 | 47,330 |
| Miscellaneous | 80 | 684 | 534 | 170 | 124 | 63 | 39 | 1,714 |
| TOTAL | 1,217 | 52,541 | 103,086 | 63,266 | 42,374 | 26,948 | 23,168 | 312,600 |
| BEETLES: | | | | | | | | |
| *Ahasverus advena* | 1,520 | 9,663 | 2,983 | 2,915 | 1,110 | 1,238 | 624 | 20,053 |
| *Cryptophagus* sp. | 950 | 5,855 | 1,866 | 318 | 27 | 32 | 422 | 9,470 |
| *Typhaea stercorea* | 2,745 | 14,755 | 9,222 | 4,178 | 1,549 | 3,399 | 3,579 | 39,427 |
| *Laemophloeus* sp. | 0 | 422 | 2,475 | 3,229 | 2,785 | 683 | 155 | 9,749 |
| *Carpophilus hemipterus* | 9,440 | 54,728 | 56,044 | 20,620 | 6,411 | 4,583 | 6,849 | 158,675 |
| Miscellaneous nitidulids | 63 | 386 | 673 | 1,896 | 1,678 | 753 | 1,023 | 6,472 |
| Dermestids | 222 | 1,460 | 3,693 | 16,270 | 81,414 | 22,068 | 802 | 125,929 |
| *Oryzaephilus surinamensis* | 0 | 1 | 0 | 20 | 151 | 7 | 1 | 180 |
| *Tribolium castaneum* | 0 | 20 | 5 | 2 | 377 | 2,719 | 338 | 3,461 |
| *Scobicia declivis* | 291 | 620 | 35 | 0 | 0 | 0 | 0 | 946 |
| TOTAL | 15,231 | 87,910 | 76,996 | 49,448 | 95,502 | 35,482 | 13,793 | 374,362 |
| TOTAL MOTHS AND BEETLES | 16,448 | 140,451 | 180,082 | 112,714 | 137,876 | 62,430 | 36,961 | 686,962 |

the months of greatest activity. Study of the short-interval records shows that there was a small amount of flight throughout the day when the temperature was above 65 degrees, that there was a period of increased activity for two hours late in the afternoon, and that the greatest flight occurred from about 30 minutes before sunset to 15 minutes after.

*Cryptophagus* sp., probably composed in the main of the species *inscitus* Casey, is the third evening flier that was most plentiful in May. Flight during the hours of strong sunlight was uncommon. During the day there were two periods of active flight: one, when the greatest numbers were on the wing, began 60 to 30 minutes before sunset and lasted until about one hour after; the second extended from shortly before until just after sunrise. None of these insects were taken

The lead cable borer, although not considered a pest of stored dried fruits, was recorded incidentally, as it has caused trouble in recent years in local wineries by boring into wine containers. It has been found infrequently in dried figs. The net records show that flight activity began on April 18 and ceased on June 25. The peak of the season occurred between May 9 and 15, when 418, or 60 per day, were taken.

A carabid beetle, *Plochionus pallens* (F.), has been found occasionally in raisins and in webbing beneath stacks of boxes of raisins. Its most active flight extended from August 6 to September 14, during which period an average of 36 per day were taken. The short-interval observations of September 7–8 showed that the most active flight occurred from 40 minutes to 1 hour and 40 minutes after

sunset, that is, between the end of early twilight and complete darkness.

The abundance of the saw-toothed grain beetle in the raisins was determined by examining samples of the stored fruit. The infestation was found to range between 4,300 and 46,000 adults per ton. There were more than 15,000 tons of fruit in the yard while the net was in operation, and some 20,000 tons additional were stored within a radius of a quarter of a mile. During the season 180 individuals were counted from the net catches. August was the month of greatest activity, when 151, or 84 per cent of the total, were recorded. Whether the 180 beetles were captured while they were flying or while they were drifting in the wind after falling from the stacks and sheds was not determined. In view of the large population in the storage yard the extent of movement through the air, as indicated by catches in the net, was insignificant.

The numbers of insects recorded during the season are summarized by species in table 1.

SUMMARY AND CONCLUSIONS.—A motor-driven rotary net, operated in a raisin storage yard at Fresno, Calif. from April 14 to October 31, 1938, gave data on the comparative abundance from day to day of 16 species or groups of insects. The raisin moth and the Indian-meal moth made up 94 per cent of the moths recorded. Among the beetles the nitidulids and the dermestids were the most plentiful in the air. The most abundant insect in stored raisins, the saw-toothed grain beetle, was taken from the air in very small numbers.

The flight habits of 12 species or groups were studied in detail by means of collections made at intervals of 15 minutes on 10 days. The dried fruit beetle and the dermestids were shown to be insects which fly during daylight hours; the other beetles recorded were predominantly crepuscular in their flight habits. All the species of storage moths captured flew during the night, flight usually beginning about sunset. On warm nights the raisin moth and *Ephestiodes nigrella* were on the wing until sunrise.

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# The Discovery of an Alfalfa Weevil (*Hypera brunneipennis* Boheman) in Arizona

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On April 11, 1939, the writer visited the garden on the Valley Farm of the University of Arizona at Yuma for the purpose of collecting aphids. He was accompanied and assisted by Mr. Ted Hendrixson, assistant horticulturist at the farm. In examining fenugreek (*Trigonella foenumgraecum* L.), a small, white, lace-like, silken cocoon containing a pupa was found. This attracted the writer's attention because he knew of no insect on alfalfa in central or southern Arizona which would make a cocoon of this type. Further examination of the fenugreek revealed that considerable feeding had been done by some insect. Excrement was noted on the leaves and adult weevils were found on the plants.

Alfalfa was next examined and a rather severe infestation was found. Some plants were seen to be badly injured while others were injured less severely or not at all. Cocoons were found fastened to the leaves of the injured plants and to dry leaves and among the stems at the bases of these plants where they were particularly numerous. Green larvae were found on the ground where they had fallen when the plants were disturbed. The writer recognized these at once as being larvae of weevils. Upon closer examination, the larvae were found to have a light stripe down the back and a brown or dark brown head. Pupae were found in cocoons and adults were present on the plants and on the ground under the plants. The larvae, pupae and adults were numerous.

On the same day Mr. Robert Flock, a graduate student in the University of Arizona, was sweeping alfalfa in a date garden on the Mesa Farm which is located near the Valley Farm. Among the insects which he took were adult weevils and green larvae of the weevils.

The writer suspected that the weevil

which had been found was the alfalfa weevil (*Hypera postica* Gyllenhal). On April 13, he was able to examine a weevil under the binocular microscope and compare it with *H. postica* with which it seemed to be identical. Both Mr. J. L. E. Lauderdale, at that time district entomologist, and the writer were convinced that the weevil was the alfalfa weevil and that it presented a serious problem, being the first record of alfalfa weevil in Arizona south or east of the Colorado River.

On April 15, the writer sent specimens of the weevil for identification to Mr. C. F. W. Muesebeck of the Bureau of Entomology and Plant Quarantine at Washington, D. C. Dr. R. S. Hawkins, Acting Dean of the College of Agriculture, Dr. C. T. Vorhies, head of the Department of Entomology and Economic Zoology and Dr. Oscar C. Bartlett, State Entomologist, were notified of the discovery of the weevil.

On April 17, the writer returned to Yuma and with Mr. Lauderdale continued to scout for the weevil for the next few days and found it present on both sides of a public highway for a distance of about eight miles. It was found on sour clover (*Melilotus indica* All.), bur clover (*Medicago hispida* Gaertn.) and alfalfa (*Medicago sativa* L.). Sour clover was an especially favorable host plant. Adults, larvae and cocoons containing pupae were taken. Adults and particularly larvae may be collected by sweeping favorable host plants with an insect net.

On April 23, the writer returned to Tucson where a telegram awaited him from Mr. C. F. W. Muesebeck. This gave the official determination of the insect as *Hypera brunneipennis* Boheman. A letter from Mr. Muesebeck followed in which he stated that Mr. L. L. Buchanan had made the determination and that the insect was originally described from Egypt and was also reported from Ethiopia. The discovery of this weevil at Yuma, is apparently the first time that it has been found in the Western Hemisphere.

On April 24, the problem of the newly discovered alfalfa weevil was officially referred to the Bureau of Entomology and Plant Quarantine.

How and when *H. brunneipennis* was introduced into the Yuma area is unknown. It apparently was not present in March, 1933, since at that time about 1,500 one year old alfalfa plants were brought from Yuma to the new university farm at Tucson where they were set out. These plants came from the garden of the Valley Farm at Yuma where the weevil was discovered. The original plants are no longer standing but alfalfa has been grown continuously in the same field at Tucson since 1933. On April 29, 1939, this alfalfa was carefully swept with an insect net by the writer. A small number of sour clover plants which grew at the edge of field were also swept. No weevils or other evidences of infestation were found in this field. Although this indicates that the insect was not present on the Valley Farm in 1933, it may even then have been present in some other locality in the Yuma area.

The writer has made a few observations on *H. brunneipennis*. On April 27, some of the weevils were placed on tips of alfalfa in petri dishes at ordinary room temperatures. On April 28, in order to keep the alfalfa tips fresh, a pad of moist cotton was placed over the cut ends in each petri dish. The weevils drank copiously from the moist cotton at once. Their behavior indicates that they are strongly attracted to moisture.

In these studies, the last emergence from the cocoons occurred on May 1. From April 27, when they were placed in the petri dishes to May 6, the weevils fed voraciously upon the tips. First they ate the flowers and young unopened flower buds and shredded the leaves. Finally they disregarded the flowers and leaves and fed on the stems, making elongated scores in them.

After May 6, a change in the behavior of the weevils took place. Both the old and younger weevils were less active; they stopped feeding entirely and rested quietly among the tips or around the moist cotton. Often clusters of the weevils were found on top of or under the moist cotton pad.

In these studies, the weevils did not attempt to fly but tried to hide among the leaves or feigned death when disturbed. There is, however, evidence to show that the weevils are good fliers under natural conditions. They have the ability to cling tenaciously to objects with their sharp tarsal claws.

In reply to an inquiry by the writer con-

cerning this weevil, a letter dated May 25, 1939, was received from Dr. M. T. Sayed of the Ministry of Agriculture, Entomological Section, Cairo, Egypt. In this letter, he stated that *H. brunneipennis* is an insect of minor importance in Egypt and that there is little literature concerning it. Dr. Sayed included a typewritten copy of a publication on the weevil by Willcocks (1922). In this publication Willcocks refers to the weevil as *Hypera variabilis* Herbst. According to Professor H. Priesner, whom Dr. Sayed consulted, the name should be *H. brunneipennis* Boheman. Dr. Sayed stated that the true *H. variabilis* Herbst is very rare in Egypt.

The weevil, which is known in Egypt as the berseem weevil is held in check by pasturing, cutting and rapid growth of the berseem or Egyptian clover upon which it feeds. Pasturing is the most effective method of control. The weevils remain inactive from early May until late December, under the bark of trees, in sheds or under any shelter they can find. They then move to the fields where they are found until early May. The larvae are most numerous in early April.

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# Life History of the Western Strawberry Leaf Roller with Notes on Its Control

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The western strawberry leaf roller, *Anacampsis fragariella* Busck,* has been observed as a minor pest of strawberries in western Oregon for a number of years, but it has only occasionally been abundant enough to cause severe injury. During the seasons of 1937 and 1938 preliminary observations on the life history and the effect of certain cultural practices on leafroller populations were carried out.

DISTRIBUTION.—Busck (1904) described *A. fragariella* from Pullman, Washington. Essig (1926) mentioned an outbreak at Hopland, California, and Knowlton (1937) records its occurrence in Utah. Aside from the records mentioned above, this insect has been found in numerous localities throughout the Willamette Valley in western Oregon and as far south as Grants Pass, Oregon.

ECONOMIC IMPORTANCE.—Severe damage to strawberries by this insect has occasionally been observed in western Oregon, but in no locality has it been found to be a serious problem year after year. These fluctuations in population are apparently due to the action of parasites and to the fact that strawberry plantings are usually removed after four to five years.

The larvae tie the leaflets together with webbing and feed inside the rolled leaves. Under conditions of heavy infestation, the plants take on a ragged appearance, and the injury to the leaves may seriously reduce the vitality of the plants.

DESCRIPTION OF STAGES.—The egg is white in color when first deposited, but changes to a salmon-orange color after 24 to 48 hours. The egg is 0.6 mm. long and 0.3 mm. wide, oval, circular in cross-section, and the surface is entirely covered by a maze of prominent reticulations.

The larvae are about 1 mm. in length when first hatched and 13 to 15 mm. long when full grown. They are white to cream in color with the smaller larvae often having a somewhat pinkish tinge. The head capsule is of a light brown or tan color. Each body segment is marked with from three to five black dots laterally and when viewed from above there appears to be a triple row of black spots on each side of the mid-dorsal line. The thoracic markings are usually larger and more conspicuous than the abdominal markings.

The pupae average 8 mm. in length and vary in color from a light to a dark brown. Pupation occurs within the rolled leaves and the pupae are naked, as no cocoon is formed.

The adults are 7 to 8 mm. in length and

* Lepidoptera: *Gelechiidae.*

have a wing expanse of 15 to 16 mm. The body and legs are brown. The fore wings are brown with a silvery sheen and have a darker, mahogany brown transverse band about one-third of the distance from the apex of the wings. The hind wings are a dark fuscous. Males and females are very similar in size and markings. However, they may be distinguished by the difference in the shape of the apex of the abdomen, which is acute in the male and rather blunt in the female.

LIFE HISTORY.—Observations show that there is but one generation a year in western Oregon. The winter is passed in the egg stage on the old strawberry leaves.

**Table 1.—Seasonal history of *Anacampsis fragariella* Busck. 1937 and 1938.**

| STAGE | MAR. | APR. | MAY | JUNE | JULY | AUG. | SEPT. | OCT. |
|---|---|---|---|---|---|---|---|---|
| Larva | | | | | | | | |
| Pupa | | | | | | | | |
| Adult | | | | | | | | |
| Egg | | | | | | | | |

The eggs hatch in late April and early May and the small larvae feed on the new growth of the strawberry plants, typically between the folds of the young developing leaflets. Later the larvae roll the leaflets together, fastening them with webbing, and complete their development inside. The larvae are not profuse web spinners, as but little webbing is found. Growth is completed in from 5 to 6 weeks after hatching.

The larvae pupate during late June and early July and the pupal period requires two to three weeks. The average length of the pupal period for 17 individuals reared under laboratory conditions in 1937 was 12.2 days, and for 12 individuals observed in 1938 under insectary conditions was 18.5 days.

Moths emerge during the middle and latter part of July. The female has a definite pre-oviposition period of two to three weeks. Observations on 12 pairs of moths in 1937 under laboratory conditions showed an average pre-oviposition period of 16 days, and in 1938 six pairs of moths observed in the insectary showed an average pre-oviposition period of 17.8 days. The female moths deposit eggs over a period lasting as long as a month. For the same pairs of moths described above, the oviposition period in 1937 averaged 18.7 days and in 1938 averaged 20 days. The average number of eggs deposited per female moth in 1937 was 100.1 and 1938 was 43.3. As many as 169 eggs have been deposited by a single female under insectary conditions. The eggs are deposited on the undersides of the strawberry leaves along the mid-rib and larger leaf veins. Adult moths fed on 10 per cent sucrose solution have been kept alive for over two months under insectary conditions. The average length of adult life of the females was 41.5 days in 1937 and 60.1 days in 1938, and for the males was 48.7 days in 1937 and 53 days in 1938.

Leaf roller development was approximately the same for the seasons of 1937 and 1938.

**Table 2.—Effect of cultural practices on western strawberry leaf roller populations 1937 and 1938.**

| TREATMENT | NO. OF PLANTS EXAMINED | NO. OF INJURED LEAVES PER 10 PLANTS | PER CENT REDUCTION |
|---|---|---|---|
| A. 1937 Counts—Old planting[1] | | | |
| No treatment | 130 | 17.3 | — |
| Topped | 130 | 13.8 | 20.2 |
| Covered | 30 | 14.3 | 17.3 |
| Topped and covered | 80 | 1.3 | 92.5 |
| B. 1937 Counts—Young planting[2] | | | |
| No treatment | 50 | 2.8 | — |
| Topped | 50 | 4.8 | None |
| Covered | 10 | 4.0 | None |
| Topped and covered | 20 | 0.5 | 80.8 |
| C. 1938 Counts[3] | | | |
| No treatment | 90 | 17.4 | — |
| Topped | 50 | 11.8 | 33.3 |
| Covered | 30 | 14.0 | 22.2 |
| Topped and covered | 30 | 0.7 | 96.0 |
| D. Summary of all counts for 1937 and 1938 | | | |
| No treatment | 270 | 14.7 | — |
| Topped | 230 | 11.4 | 22.4 |
| Covered | 70 | 12.7 | 13.6 |
| Topped and covered | 130 | 1.1 | 92.5 |

[1] 4 and 5 years old in 1937.
[2] 3 years old in 1937.
[3] 4 years old in 1938—same planting as B.

*Parasites.*—Knowlton (1937) records three species of Hymenopterous parasites of *A. fragariella* in Utah, *i.e.*, *Euochus pleuralis* Cress., *Spilochalcis delumbis* (Cress.), and *Goniozus platynotae* Ashm. *Microgaster phthorimaeae* Mues. and

*Microbracon gelechiae* (Ashm.) have been reared from *A. fragariella* in Oregon.*

*Control*—During 1937 and 1938 observations were made on the effect of certain cultural practices designed for strawberry crown moth control on leaf roller populations. These observations were made on a planting located on the Oregon State Agricultural Experiment Station farm near Corvallis which was in use for experimental work on the control of the strawberry crown moth. Treatments consisted of topping, covering, and both topping and covering. The plants were topped with an ordinary mower, and covering was effected by the use of a cultivator which had the shovels adjusted to throw the dirt over the plants.

Counts of the number of injured leaves on 10 plants were made in each row of the planting. In 1937 the plants varied in age from 3 to 5 years. After harvest in 1937 the 4 and 5 year old plants were plowed under so that only part of the planting was available for observation in 1938. The plants were treated, *i.e.*, topped, covered, or topped and covered, immediately after harvest in 1936 and 1937. At this season the moths are flying and the effect of the treatments in preventing oviposition is shown in the tabulation of results in table 2. The failure of topping or covering alone to give control may be explained by the fact that topping with a mower leaves some of the basal leaves on the plants, and the cultivator fails to cover completely plants which have not been topped, leaving some of the upper leaves exposed. Very few exposed leaves can be found on plants which have been both topped and covered. Experimental work on hand topping was not carried on during these two years.

Experimental work on the effect of topping and covering with soil and other material on growth and yield of strawberries is now in progress at the Oregon Experiment Station. Topping alone apparently has no injurious effects on the plants. However, as severe a practice as topping and covering with soil would probably be advisable only under conditions of heavy infestation. The application of some insectice might be more practical, although no studies were made along this line.

SUMMARY.—Data are given covering two years observations on the life and seasonal history of the western strawberry leaf roller, *Anacampsis fragariella* Busck. Observations on cultural control indicate that topping and covering strawberry plants after harvest may give a high degree of protection against oviposition by the moths.

* Determinations made by Dr. C. F. W. Muesebeck, Bureau of Entomology and Plant Quarantine.

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# Living Parasitic and Predaceous Insects for Classroom Use

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Practically all high school, college and university courses in biology, zoology and entomology include at least casual reference and frequently more extended attention to insect parasites and to biological control of insects, even though comparatively few students actually have opportunity to manipulate and observe the activities of living representatives of important parasitic and predaceous groups. The introduction of such materials into teaching programs helps to illustrate factors in the natural and biological control of insects for the benefit of students preparing to teach and serves as an important element of groundwork in entomology for those who specialize in this subject.

Descriptions of breeding technique for educational and research purposes have been published from time to time regarding various parasitic and predaceous in-

sects. It is not the purpose of this paper to review these or to describe in detail special methods and simplified equipment devised by the writer, but rather to present a brief survey of the subject in order to direct attention to certain living materials which are particularly suited on account of host relationships for classroom demonstrations and observations, as well as for student research projects.

IMPORTANCE OF SUITABLE HOST INSECTS.—Since it is obviously impracticable for the biology or entomology department of each educational institution to acquire from local sources, and to maintain indefinitely, cultures of beneficial insects which may be needed for classroom use, first consideration must be given to the character of the host insects. If not readily or conveniently obtainable locally they must be types of such wide distribution throughout the country that they can be shipped, interstate and intrastate, without troublesome formalities. In general, the host insects which appear to answer this requirement best are those of the widest distribution, as pests of stored grain, cereal and other food products, furniture and clothing. Such insects are unavoidably transported in commerce to such an extent that the few specimens required for instructional and investigational use are insignificant.

For a list and bibliography of parasitic and predaceous insects which normally utilize cereal and grain pests as hosts we are fortunate in having a recent comprehensive publication by Cotton and Good (1937). Many of the published records, however, are based on occasional discoveries and are now evidenced only by museum specimens and by printed descriptions and records. Although natural cultures no doubt still exist somewhere in the country, in many cases sources of living material are entirely unknown to entomologists. Others are more common and can be obtained by more or less persistent efforts in most localities. In this respect they are similar to cultures of protozoans, other lower animals and algae commonly used in the teaching of biology. The cost of securing and maintaining a series of such cultures for biology classes, except in the large universities, is ordinarily prohibitive, and the commercial biological supply house meets the need at reasonable cost. Likewise, cultures of many representative parasitic and predaceous insects, together with host materials, are now available from commercial sources.

In addition to the parasitic and predaceous insects which normally utilize as hosts certain insects infesting grain and cereal products, there are others which may utilize such hosts in the laboratory under proper conditions. Examples of this are species of *Trichogramma* and of *Chelonus*. For a representative of the important hymenopterous family, *Encyrtidae*, the host insects of which cannot be shipped interstate, the problem is solved by first securing locally a colony of common mealybugs, *Pseudococcus citri* Risso, and developing this host on potato sprouts before securing adults of the Sicilian mealybug parasite, *Leptomastidea abnormis* Girault, which is an important factor in the biological control of its host in California citrus orchards and in some greenhouses.

Similarly, host species of aphids secured locally may be cultured on suitable plants preparatory to classroom demonstrations and studies of species of *Aphelinidae* and of the braconid sub-family, *Aphidiinae*. Techniques in this connection have been described by Wheeler (1923) and Griswold (1937). In the writer's opinion hymenopterous parasites of the common cabbage aphis, *Brevicoryne brassicae* Linn. are the most suitable for the purposes herein considered, largely because of the wide distribution of the host insect and the ease of growth of the seedling food plants.

Turning again to the parasites which utilize as hosts insects infesting cereals, food products and clothing, the writer has found representatives of five important families particularly well adapted for small-scale culturing—namely: *Bethylidae*, *Braconidae*, *Ichneumonidae*, *Pteromalidae* and *Trichogrammatidae*. These, with the *Encyrtidae* and *Aphelinidae* already briefly discussed, from the standpoint of one engaged in an entomological supply business of this kind, appear to offer materials upon which student work may be conveniently based. For the more elementary courses a selection of at least two or three of the more easily reared forms may be made for individual manipulation and study, while it is suggested that the culture of additional ones for the benefit of

all the members of one or more classes may be assigned to students showing special aptitude for such work.

AVAILABLE SPECIES OF PARASITIC INSECTS.—The biologies of two representatives of *Bethylidae, Cephalonomia gallicola* Ashm. and *C. tarsalis* Ashm., have been investigated by Kearns (1934) and Powell (1938). The former is more readily reared, and the drugstore beetle, one of its hosts, can be produced in the laboratory more readily than other species. Among other members of the group, the *Tribolium* larval and pupal parasite, *Rhabdepyris zeae* Turner and Waterston, is one which is not now available in this country as a culture, so far as the writer knows, but which would undoubtedly prove a very desirable addition to this list.

The family *Braconidae* offers several representatives well adapted for classroom use. Deserving of first consideration is the well known *Microbracon hebetor* Say (*juglandis* Ashm.) made notable by the studies of Doten (1911) and extensively studied in many phases of its biology by P. W. Whiting *et al.*[1] A general account of the biology and economics of this insect has been reported by Simmons, Reed and McGregor (1931). It is preeminently a parasite of stored product pests, particularly larvae of the Mediterranean flour moth and the Indian-meal moth. Certain species of the genus *Chelonus*, on the other hand, utilize certain stored product pests as hosts in the laboratory but are not known to do so naturally. Two species of this genus, *C. annulipes* Wesm. and *C. blackburni* Cam. have been reported by Bradley and Arbuthnot (1938) and by Noble and Hunt (1937) as being capable of using the Mediterranean flour moth as a laboratory host. The latter also readily parasitizes the Angoumois grain moth. Oviposition of the parasite in the host egg and the development of the parasitic larva in the host larva gives a special interest to these species. It is not unlikely that two others species, *C. texanus* Cress. studied by Pierce and Holloway (1912), Luginbill (1928), and Vickery (1929) and *C. shoshoneanorum* Vier., studied by Graf (1917), may be bred on the same laboratory hosts. The most thorough study of the biology and morphology of a member of the genus has been made by Vance (1932) with *C. annulipes* in connection with European corn borer investigations.

*Apanteles carpatus* Say, a parasite of the webbing clothes moth, is another interesting and easily bred braconid parasite. This insect has been under observation by the writer for several years but no males have been seen. The species evidently exhibits parthenogenesis of the thelyotokous type as a normal method of reproduction. While it is, itself, little known, the biology of another member of the genus, *A. thompsoni* Lyle, has been thoroughly studied by Vance (1931).

Among the *Ichneumonidae*, several of which have been recorded as parasites of the Mediterranean flour moth and the Indian-meal moth, the species *Idechthis canescens* Grav. is the one recommended. While this species is of little economic importance, it is easily reared when one has a good stock of host larvae two-thirds grown or larger in size. This species offers a good opportunity for biological studies.

The family *Pteromalidae* is especially rich in material suited for classroom use. Frequently, in the fall, pupae of the widely distributed cabbage butterfly may be found heavily parasitized by *Pteromalus puparum* Linn., but not all teachers of biology and of entomology have easy access to a cabbage patch. Among the parasites of this family which use cereal pests as hosts are *Habrocytus cerealella* Ashm., *Aplastomorpha calandrae* How., *Lariophagus distinguendus* Foerst and *Chaetospila elegans* Westw. *Dibrachys caeus* Walk and *D. clisiocampae* Fitch may also be mentioned, although the writer has not had personal experience in breeding these two species. Noble (1932) and Fulton (1933) have treated in detail the morphology and biology of *H. cereallae*, which is readily reared from the larvae of the angoumois grain moth and which exhibits a peculiar combination of predatory habits of the cannibalistic type followed by ectoparasitism of the moth larva.

Cotton (1923) in a paper on *Aplastomorpha calandrae* How. has described a method of inducing oviposition in host larvae, particularly of the rice weevil, confined in gelatin capsules, which greatly facilitates the manipulation and observation of this parasite by students and makes it an outstanding species for classroom use.

[1] See Index V, American Economic Entomology, 1938.

The more important references to *L. distinguendus* are in European literature. This species is of special interest since two species of hymenopterous parasites which attack cereal products, *Idechthis canescens* Grav. and *Microbracon hebetor* Say, have been recorded as hosts. If this parasite would readily attack the latter, as a secondary parasite, it would provide an opportunity for observing in detail the process of oviposition and other features of the insect's biology which are not as readily observed with more normal concealed hosts such as the drugstore beetle, *Stegobium panaceum* L. However, the writer's attempts to induce such secondary parasitism have been unsuccessful.

A notable feature of *L. distinguendus* is the remarkable variation in size of the adults which commonly range from 1.25 mm. to 2.75 mm. These measurements apply to specimens bred from the drugstore beetle and the cowpea weevil. The ant-like *C. elegans* is fairly prolific as a parasite of the granary and rice weevils and offers an opportunity for genetic studies in wing inheritance. The writer has also bred this species from the drugstore beetle. A brief note on the apterous condition of a series of males was made by Chittenden (1897). The writer has found a small percentage of apterous specimens of both sexes.

The tachinid parasite of the Indian-meal moth, *Epigrimyia floridensis* Towns, briefly recorded by Simmons, Reed and McGregor (1931), may fill the need for a representative of the Diptera. The possibility that the imported tachinid parasite of the gypsy and brown-tail moths, *Compsilura concinnata* Meighan, may utilize the larvae of one of the meal and flour moths as host material is indicated by the extensive list of host species already recorded by Schaffner and Griswold (1934). The biology of this species has been treated by Culver (1919), while his description of breeding technique will prove a valuable aid in utilizing any species of tachinid in classroom work.

Representatives of the other three insect orders containing insects which are recorded as parasitic on other insects, the Lepidoptera, Coleoptera and Strepsiptera, appear at this time to be unsuitable for the type of classroom use here considered, and these groups are omitted, therefore, from this discussion.

PREDACEOUS INSECTS.—Sweetman (1936) lists 167 families which contain insects predatory on insects, as compared with only 87 families containing species parasitic on insects. It might appear that predatory species of insects would therefore offer proportionally more opportunities for selecting desirable material and for adapting breeding methods for classroom requirements. However, predatory habits of insects are not as specialized and diversified as is the case with parasitic habits and comparatively only a few families of these insects are of notable economic importance.

Again, many important predators are not suited for mass production by an entomological supply house or for small unit production by students in the classroom. As examples, mention may be made of representatives of the leading dipterous families of predators, *Bombyliidae*, *Asilidae* and *Syrphidae*, all of the Odonata and many other groups.

The most important groups of insect predators are the coleopterous families, *Carabidae* and *Coccinellidae*. These should be represented in any attempt to give students an opportunity for personal observations of the life history and habits of representatives of the leading beneficial groups of insects. Another coleopterous group which may conveniently be represented is the Cleridae, noteworthy species of which family prey on bark beetles. Predaceous Heteroptera and Neuroptera afford examples which may readily be bred by students and many of which are at the same time of especial interest because of their well-established economic importance.

The Australian mealybug destroyer, *Cryptolaemus montrouzieri* Muls., while highly specialized in its adaptation to host insects, is one which is particularly well suited for classroom use. A supply of common mealybugs, *Pseudococcus citri* Risso should be secured locally as suggested for breeding the encyrtid mealybug parasite, *L. abnormis*. This mealybug culture should be developed on potato sprouts grown in a dark room before securing the stock of coccinellids, following the general procedure used in mass production for biological control described by Smith and Armitage (1931). These beetles can be shipped with no appreciable loss by air mail or regular mail and

kept for a considerable time, frequently up to five or six weeks, with angoumois grain moth eggs for food. Some species of aphids are also acceptable as food, but ordinarily, for reproduction, certain species of mealybugs which produce a flocculent waxy secretion appear to be necessary. The writer has noted an exception in one instance where he liberated a number of adults on chrysanthemum plants infested by an unidentified aphid, no mealybugs being present, and in due time found large numbers of larvae of *Cryptolaemus* working actively and effectively on the aphid along with other predators. Investigations are under way along new lines with the object of inducing reproduction of this ladybird without living mealybugs. If this can be accomplished, the growth and development requirements can be supplied by angoumois grain moth eggs, as heretofore mentioned.

Representatives of the family *Carabidae*, particularly of the genus *Calosoma*, may be bred in insect cages or screened jars and fed principally or exclusively upon common granary and flour pests such as mealworms and larvae of the Mediterranean flour moth and of the Indian-meal moth. The extensive investigations of the imported *Calosoma sycophanta* L. reported by Burgess (1911) and Burgess and Collins (1915), will serve as important references even though this species may not prove to be as suitable for small-scale production as some of the more common native species.

A representative of the family *Cleridae*, *Thaneroclerus girodi* Chevrolat, and its work as an enemy of the cigarette beetle, has been described by Runner (1919). Although no host insects other than the cigarette beetle are reported, it seems likely that the drugstore beetle might serve as a substitute. This would greatly facilitate classroom use of this predator. However, the tobacco beetle can be successfully cultured if necessary.

Certain predaceous pentatomids may be bred continuously for student observation and study, using cereal pests as food materials. Two of the best known representatives of this group are the spined soldier bug, *Apateticus maculiventris* Say, observations on the biology of which have been reported by the present writer (1906) and *P. serieventris* Uhler, on the biology of which Prebble (1935) has made extensive studies. The writer has more recently used the eggs of the angoumois grain moth and larvae of the Mediterranean flour moth and of the Indian meal moth in the successful rearing of the spined soldier bug. For the first instar, which is phytophagus, use was made of the growing tips of various plants, such as hibiscus and seedling asters, to which the insects were transferred within a few hours after hatching. Numerous other predaceous Heteroptera may be bred in confinement, but few are suitable for small unit and continuous breeding.

The biology of representatives of the neuropterous family *Chrysopidae* have been studied by Wildermuth (1916) and Smith (1922). The California green lacewing, *Chrysopa californica* Coq., in the first instar, feeds readily upon newly hatched larvae of the angoumois grain moth. In this stage the lacewing larva seems unable to pierce the egg chorion of the grain moth and, in fact, does not attempt to do so. Immediately upon getting within reach of a crawling larva of the grain moth, this voracious feeder quickly disposes of the caterpillar. In the second instar the eggs of the grain moth will serve as food material, although the lacewing larva experiences much difficulty in piercing the chorion, usually succeeding, after many attempts, in forcing one of its sharp mandibles through the micropylar end. In the third and final instar the eggs of the grain moth are sucked at a rapid rate. Several *Chrysopa* larvae each, within a period of twenty-four hours, devoured upwards of 900 eggs, immediately after which the larva rested or began spinning its cocoon. It is believed that eggs and pupae of this valuable predator can be stored for considerable periods and that continuous breeding in the laboratory or classroom can be readily maintained by means of eggs and newly hatched larvae of the grain moth. This diet may be supplemented with aphids and mealybugs if available.

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THE COLORADO quarantine relating to the alfalfa weevil was revised, effective November 1, 1939, to add Yuma County, Arizona to the area designated as infested with *Hypera postica*, Gyll., and to add Larimer County, Colo., to the area in that State to which the restricted products may be shipped, making 16 counties in Colorado which are outside the protected area.

# Control Experiments on the Tomato Fruitworm in Southern California During 1937

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A study of the tomato fruitworm (*Heliothis obsoleta* (F.) ) and its control was begun in California and Utah in the 1936 season. In California, in 1936, the life-history studies were made by the junior author and preliminary control experiments conducted by J. C. Elmore, of the Bureau of Entomology and Plant Quarantine. Similar studies in Utah are being made by H. E. Dorst of the same bureau in cooperation with the Utah Agricultural Experiment Station. The work reported herein was carried on in 12 fields of tomatoes in southern California during the 1937 season, and the experiments covered the treatment of early-market, canning, and late-market tomatoes.

Some 523 field plots were included in the experiments, most of which were plots on which various dust mixtures were applied, while additional plots that were treated for the tomato pinworm (*Gnorimoschema lycopersicella* (Busck.)) were also checked for fruitworm control. The plots ranged in size from one twenty-sixth to one-fifth of an acre, with an average of about one-eleventh of an acre. The usual arrangement of the plots was a Latin square with five replications, but in some of the fields the plots were arranged at random with two, three, and four replications. In general, three applications of insecticides were made, beginning when the plants had a spread of about 1 foot, the second and third applications following

**Table 1.—Tomato fruitworm experiments in the Wm. Greeley field, Costa Mesa, Calif., 1937.***

| Treatment | Number Tomatoes Examined | Number Tomatoes Injured | Per Cent Injured | Per Cent Control |
|---|---|---|---|---|
| Calcium arsenate 20%, hydrated lime 80%† | 8056 | 1211 | 15.0 | 11.8 |
| Calcium arsenate 40%, hydrated lime 60% | 5950 | 650 | 10.9 | 35.9 |
| Calcium arsenate undiluted | 7337 | 488 | 6.5 | 61.8 |
| Natural cryolite 20%, talc 80% | 7331 | 813 | 10.8 | 36.5 |
| Natural cryolite 40%, talc 60% | 6140 | 367 | 6.0 | 64.7 |
| Natural cryolite 60%, talc 40% | 8024 | 287 | 3.6 | 78.8 |
| Cubé (1% rotenone)‡ | 6773 | 1080 | 16.0 | 5.9 |
| Cubé (1½% rotenone) | 6412 | 1087 | 16.9 | .6 |
| Cubé (2% rotenone) | 6675 | 957 | 14.3 | 15.9 |
| Phenothiazine 10%, talc 90% | 6728 | 896 | 13.3 | 21.8 |
| Phenothiazine 20%, talc 80% | 7891 | 838 | 10.6 | 37.7 |
| Phenothiazine 30%, talc 70% | 7303 | 727 | 9.9 | 41.8 |
| Cuprous cyanide 10%‡ | 7253 | 995 | 13.7 | 19.4 |
| Cuprous cyanide 20% | 7056 | 787 | 11.1 | 34.7 |
| Cuprous cyanide 30% | 7074 | 574 | 8.1 | 52.4 |
| Checks—no treatment | 18149 | 3092 | 17.0 | — |

* Plots arranged at random in duplicate. Three applications made, June 10, June 24, and July 8.

† In this and in similar instances reported upon in this paper the proportions of each of the ingredients of the dust mixtures are expressed in terms of the percentage of the commercial grade of the insecticide used, and of the diluent, by weight.

‡ Diluent, talc.

**Table 2.—Tomato fruitworm experiments in the Mitchell Brothers field, Irvine, Calif., 1937.***

| Treatment | Number Applications | Number Tomatoes Examined | Number Tomatoes Injured | Per Cent Injured | Per Cent Control |
|---|---|---|---|---|---|
| Natural cryolite 50%, talc 50%† | 3 | 4030 | 311 | 7.7 | 54.4 |
| Natural cryolite 50%, talc 50% | 1 & 2 | 4195 | 555 | 13.2 | 21.9 |
| Natural cryolite 50%, talc 50% | 1 & 3 | 4215 | 420 | 9.9 | 41.4 |
| Natural cryolite 50%, talc 50% | 2 & 3 | 4019 | 404 | 10.1 | 40.2 |
| Checks—no treatment | | 4229 | 714 | 16.9 | — |
| Calcium arsenate 50%, hydrated lime 50% | 3 | 3755 | 511 | 13.6 | 31.7 |
| Calcium arsenate 50%, talc 50% | 3 | 4199 | 533 | 12.7 | 36.2 |
| Natural cryolite 50%, diatomaceous earth 10%, talc 40% | 3 | 3439 | 397 | 11.5 | 42.2 |
| Synthetic cryolite 50%, diatomaceous earth 10%, talc 40% | 3 | 3610 | 345 | 9.5 | 52.3 |
| Checks—no treatment | | 3636 | 724 | 19.9 | — |
| Phenothiazine 30%, wetting agent 1%‡ | 3 | 4217 | 562 | 13.3 | 22.7 |
| Cuprous cyanide 20%, wetting agent 1%‡ | 3 | 3894 | 447 | 11.5 | 33.1 |
| Calcium arsenate undiluted | 3 | 3971 | 440 | 11.1 | 35.5 |
| Calcium salt 2-4-dinitro-6-cyclo-hexylphenol 10%, talc 45%, hydrated lime 45% | 3 | 3533 | 458 | 12.9 | 25.0 |
| Checks—no treatment | | 4323 | 743 | 17.2 | — |
| Calcium salt 2-4-dinitro-6-cyclo-hexylphenol 20%, talc 20%, hydrated lime 60% | 3 | 3817 | 582 | 15.2 | 32.8 |
| Bran 20 lbs., corn oil 1½ qts., natural cryolite 1 lb. | 3 | 3623 | 419 | 11.6 | 48.7 |
| Corn meal 25 lbs., natural cryolite 1 lb. | 3 | 3608 | 334 | 9.2 | 59.3 |
| Corn meal 25 lbs., lead arsenate 1 lb. | 3 | 3646 | 359 | 9.8 | 56.6 |
| Checks—no treatment | | 3756 | 848 | 22.6 | — |

* Plots arranged as a Latin square with five replications. Three applications made, July 10, July 24, and August 7.

† In this and in similar instances reported upon in this paper the proportions of each of the ingredients of the dust mixtures are expressed in terms of the percentage of the commercial grade of the insecticide used, and of the diluent, by weight.

‡ Diluent, talc; wetting agent, a proprietary sodium lauryl sulphate.

at two-week intervals. This resulted in the third application being made at least two weeks before the start of the picking season. Usually 10 pounds of dust was used per acre for the first application, 15 pounds for the second, and 20 pounds for the third.

**Table 3.—Tomato fruitworm experiments in the E. L. Williamson field, Riverside, Calif., 1937.***

| Treatment | Number Tomatoes Examined | Number Tomatoes Injured | Per Cent Injured | Per Cent Control |
|---|---|---|---|---|
| Phenothiazine 30%† | 1417 | 153 | 10.8 | 53.2 |
| Phenothiazine 30%, wetting agent 1%‡ | 1616 | 179 | 11.1 | 52.0 |
| Cuprous cyanide 20%† | 1401 | 156 | 11.1 | 52.0 |
| Cuprous cyanide 20%, wetting agent 1%‡ | 1670 | 155 | 9.3 | 59.7 |
| Checks—no treatment | 1283 | 297 | 23.1 | — |
| Calcium arsenate, undiluted | 1361 | 148 | 9.3 | 60.4 |
| Calcium arsenate 90 lbs., dust mixture containing 3% of nicotine, 10 lbs. | 1378 | 125 | 9.1 | 62.1 |
| Corn meal 25 lbs., synthetic cryolite 1 lb. | 1677 | 173 | 10.3 | 57.1 |
| Bran 20 lbs., corn oil 1 qt., synthetic cryolite 1½ lbs. | 1680 | 170 | 10.1 | 57.9 |
| Checks—no treatment | 1364 | 327 | 24.0 | — |
| Natural cryolite 40%, talc 60%§ | 1523 | 116 | 7.6 | 58.9 |
| Synthetic cryolite 40%, talc 60% | 1347 | 125 | 9.3 | 49.7 |
| Synthetic cryolite 40%, talc 50%, diatomaceous earth 10% | 1583 | 122 | 7.0 | 62.2 |
| Synthetic cryolite 50%, talc 40%, diatomaceous earth 10% | 1364 | 83 | 6.2 | 66.5 |
| Checks—no treatment | 1461 | 271 | 18.5 | — |

* Plots arranged as a Latin square with five replications. Five applications made, July 17, July 31, August 14, August 28, and September 11.

† Diluent, talc.

‡ Wetting agent, a proprietary sodium lauryl sulphate; diluent, talc.

§ In this and in similar instances reported upon in this paper the proportions of each of the ingredients of the dust mixtures are expressed in terms of the percentage of the commercial grade of the insecticide used, and of the diluent, by weight.

The early fields were sampled by making an examination of 100 or more tomatoes per plot on the vines at the beginning middle, and end of the picking season. As the results thus obtained were only relative and did not give a true picture of the actual infestation and damage throughout the picking season, a plan was evolved whereby five plants taken at random in each plot were marked and all the tomatoes ready for picking on these plants were picked and examined for fruitworm infestation at the regular picking times during the season. In making examinations for fruitworm injury it is necessary to examine the tomatoes on the vines, because many of the infested tomatoes rot and would not be gathered in normal picking.

In tables 1, 2, and 3 the results obtained in three fields by this method of checking are shown, except that in the Greeley field (table 1) all the fruit was examined. The figures shown give only the total results, so the seasonal picture of the infestation and control is obscured.

The discussion of the insecticides used is based on the results obtained in these three and in nine other fields in which tests were made, and not all the results mentioned and dilutions used show in the tables.

The usual condition prevalent in all fields was that the maximum infestation by the tomato fruitworm came at or near the start of the picking season and infestation gradually decreased to and including the third picking. From the fourth picking on, although the percentage of infestation in the treated plots was usually less than in the untreated plots, there was no significant difference between the two groups of plots. Consequently the percentage of control shown in table 1 to 3, inclusive, based on the records for all pickings, is fairly low.

In the Mitchell field, for example, the average percentage of damage for the six pickings in the plots dusted with three applications of 50 per cent natural cryolite was as follows: 6.5, 5.5, 5.8, 5.0, 28.6, and 7.7, respectively, and for the corresponding check plots 39.0, 21.1, 10.8, 7.8, 31.7, and 16.9, respectively. The marked increase in damage at the fifth picking here was not evident in the other fields.

The third application was made on August 7 and the fourth picking was October 1 to 5, so it appears as though the maximum period over which a dust mixture is effective is about 50 days. This period would apply only to the later applications made after the plants have made approximately their maximum growth.

Insecticides Tested.—Dust mixtures were used largely in the experiments, but baits and sprays were also tested. All dust mixture applications were made with rotary hand dusters, and both sides of the plants were dusted at each application. In all the dust mixture applications an attempt was made to cover all the foliage and especially the outer foliage, as studies

by the junior author in 1936 showed that most of the eggs were laid on the outer portions of the plants. The spray applications were made with a power sprayer which maintained about 350 pounds pressure when spray guns were used, and about 200 pounds when a spray boom was used. The baits were scattered by hand over the leaves of the plants.

DUSTS.—Cryolite was the most effective and consistent dust used and was tested at 20, 35, 40, 45, 50, and 60 per cent strengths with talc as a diluent, and at 40 and 50 per cent strengths with talc as the principal diluent but with 10 per cent diatomaceous earth incorporated.* Not all the cryolite dilutions were used in all the fields, but it seems apparent that the greater the strength of cryolite the better the control obtained. The 60 per cent strength of this material, however, with talc as a diluent, was considered a little too heavy for efficient application by rotary hand dusters. In nearly every case when 10 per cent diatomaceous earth was incorporated in the 40 and 50 per cent dilutions to lighten the dust for easier application, the dusts were not so effective as dusts of the same strength with talc alone as the diluent. Natural and synthetic cryolite were used in several comparative tests, but, so far, there is no marked superiority in results of one over the other.

Calcium arsentate was used undiluted and at dilutions of 20, 40, 50, and 70 per cent with hydrated lime as the usual diluent, but with talc substituted in some of the tests. In the early fields a mixture consisting of calcium arsenate 50 per cent and hydrated lime 50 per cent was the principal insecticide tested, but from the first test it was evident that the control obtained with this material was unsatisfactory, especially when compared with a 50 per cent mixture of cryolite and talc. In the later fields the undiluted calcium arsenate (commercial grade containing 70 per cent actual calcium arsenate) was used principally; this strength was about equal, in toxicity to the fruitworm, to a 40 per cent cryolite-talc dust. One brand of calcium arsenate was used throughout the season with one exception. In this case, although slightly better results from the viewpoint of fruitworm kill were obtained, the second brand burned the leaves considerably and was inferior to a 50 per cent cryolite-talc dust. No leaf injury was evident in any of the fields dusted with the first brand. Talc appears to be slightly superior to hydrated lime as a diluent (table 2), but the superiority is not outstanding.

Phenothiazine was used in dust mixtures at strengths of 10, 20, 25, 30, and 50 per cent, diluted with talc, and with several wetting and sticking agents incorporated. In general, the results obtained with this material in dust mixtures were not satisfactory, especially in view of the fact that sprays showed considerable promise. Since an excessive quantity of dust mixture was observed on the ground under and around the plants treated with this material, it was felt that the mixture of phenothiazine with talc was not adhering to the leaves satisfactorily. The addition of 1 per cent of a proprietary wetting agent, sodium lauryl sulfate, however, did not increase the percentage of control obtained.

Cuprous cyanide was used at strengths of 10, 20, 25, and 30 per cent, diluted with talc and also with a wetting agent incorporated. This material at 20 per cent strength was equal to or superior to phenothiazine at 30 per cent strength (tables 2 and 3) but it is apparently inferior to a 50 per cent mixture of cryolite and talc.

In preliminary experiments early in the season 2-4-dinitro-6-cyclohexylphenol and its calcium salt were used on potted plants and it was found that the parent compound, even at 1 per cent strength, diluted with walnut-shell flour was highly toxic to tomato plants, while the calcium salt was fairly safe. However, it was found that it was safer to use hydrated lime as a diluent for the calcium salt rather than talc, walnut-shell flour, or redwood flour. Two preliminary field tests were made using the calcium salt at 5 and 10 per cent strengths diluted with both hydrated lime and talc, and the results indicated it to be about as effective as a 50 per cent mixture of calcium arsenate and hydrated lime. In a later test (table 2) it was used at 10 and 20 per cent strengths and the 20 per cent dust was about as effective as undiluted calcium arsenate, but caused some burning of the leaves.

* In this and in similar instances reported in this paper the proportions of each of the ingredients of the dust mixtures are expressed in terms of the percentage of the commercial grade of the insecticide used, and of the diluent, by weight.

A cubé dust mixture containing 1 per cent of rotenone was used in two early fields and in a later field dust mixtures containing 1, 1½, and 2 per cent of rotenone, respectively (table 1), but the results obtained indicate that this material is of little or no value in the control of the tomato fruitworm under the conditions of this experiment.

BAITS.—A bait made of 75 pounds of corn meal and 1 pound of lead arsenate as used for the tobacco budworm (*Heliothis virescens* (F.)) by Chamberlin and Morrill (1936) was used in two early fields with some indication of control, and in two later fields (tables 2 and 3) at the rate of 1 pound of poison (lead arsenate or cryolite) to 25 pounds of corn meal. The control obtained in both these fields compares favorably with the best control obtained with dust mixtures. and the bait is certainly worthy of further tests. The first and second applications were made at the rate of about 40 pounds per acre, and the third and following applications at from 60 to 70 pounds per acre. At a cost of about $2.50 per 100 pounds for the bait, and with ease and speed of application in its favor, as compared to hand dusting, it would seem to offer possibilities. It appears to be of little value, however, in control of other tomato pests.

A bran bait was also used in the two early fields and in two later fields (tables 2 and 3). Although the control in one case was not so good as that obtained with corn meal bait, it does have possibilities.

SPRAYS.—In an early field where the sprays were applied with the power sprayer, using spray guns, the most effective material was phenothiazine used at the rate of 3 pounds to 100 gallons of water. The following materials were also used and are listed in the order of their effectiveness: Lead arsenate 4 to 100 and 40 per cent nicotine sulphate 1 to 600; natural cryolite 4 to 100; lead arsenate 4 to 100, 40 per cent nicotine sulphate 1 to 600, and oil 2 per cent; lead arsenate 4 to 100; and cuprous cyanide 4 to 100. Sprays that showed little or no control were cubé 3 to 100; 40 per cent nicotine sulphate 1 to 600 and oil 2 per cent; and pyrethrum extract 1 to 400.

In Mitchell Brothers' field, where the spray tests were conducted primarily for pinworm control, a check on fruitworm control was made by the writers. In this field the same machine was used but the plants were sprayed with the use of a boom. The best control was obtained with synthetic and natural cryolite, 4 to 100. The following materials are listed in the order of their effectiveness: Natural cryolite 2 to 100 and oil 2 per cent for the first application and the cryolite at 4 to 100 for the second and third applications; phenothiazine 3 to 100; natural cryolite 2 to 100, 40 per cent nicotine sulphate 1 to 800, and oil 2 per cent; and cuprous cyanide 4 to 100 with and without oil 2 per cent. The ineffective materials were the same as in the other field with the addition of cubé extract 1 to 400.

NUMBER AND TIMING OF APPLICATIONS.—In the Mitchell field, (table 2) combinations of the three applications were used and it will be noted that control was reduced considerably in each case where only two applications were made. Also, the control was reduced most when the third application was omitted. In an early field the same series of applications were made using a 50 per cent mixture of calcium arsenate and hydrated lime and the results obtained were similar. In the Williamson field (table 3) five applications were made beginning at about the same time and at the same stage of plant development as in the Mitchell field. However, because of differences, either in locality or in tomato varieties, there was a big difference in the time that the two crops matured. In the Mitchell field the first picking was made the last week of August while in the Williamson field it was not made until the second week of October. Under these conditions at least the first two applications in the Williamson field were practically wasted in so far as fruitworm control was concerned. Similarly, in an early field at Costa Mesa, applications were made on April 29, May 13, and May 29, and the first picking was made June 18. The condition here was not that the fruit failed to set, as in the Williamson field, but that the heavy fruitworm infestation did not develop until the second and third pickings, so either the first application should have been delayed, two weeks here and four weeks in the Williamson field, or else an interval longer than the two weeks between applications should have been used. In southern California one of the biggest problems appears to be the timing and

spacing of the applications in relation to locality, variety, and season.

RESIDUE.—Samples of tomatoes for arsenical and fluorine residue analysis were picked in a number of the fields at or before the time of the first picking so that samples with a maximum of residue could be obtained. Preliminary analyses of these samples by chemists of state and commercial agencies indicated that when a three-week interval had elapsed between the time of the last application and the time the sample was picked, no excess residue was found. Additional investigations will be necessary, however, before definite conclusions can be reached upon the insecticide-residue phase of the tomato fruitworm problem.

SUMMARY.—Results obtained from 523 field plots of tomatoes treated to control the fruitworm (*Heliothis obsoleta* (F.)) in southern California in 1937 are given. The most promising materials were a 50 per cent cryolite dust with talc as the diluent and a bait made of corn meal 25 pounds and cryolite 1 pound. Usually three applications of each material were made, the first being applied when the plants had a spread of about 1 foot, the other applications following at two-week intervals. The dust was applied with rotary hand dusters and the bait was scattered by hand over the leaves of the plants. Sprays were also tried in several fields and the most promising was phenothiazine, 3 pounds to 100 gallons of water.

## LITERATURE CITED

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# The Distribution of Injurious Thrips in the United States

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Thrips generally have been considered by entomologists as of minor importance. This, perhaps, is still true when they are compared, for example, with wireworms, grasshoppers, or aphids. However, the onion thrips is often as important to the onion grower as is the codling moth to the orchardist. The increasing importance of thrips as vectors of plant disease places them in the same category with aphids and leafhoppers. The recent example of the gladiolus thrips, first described in 1930, its rapid spread over North America and its rise to the position of the major pest of gladiolus, illustrates the possibilities among members of this group of insects as future pests.

Since the first realization that these tiny insects were the cause of much injury heretofore overlooked, the presence of thrips in the majority of the agricultural areas of the United States has been recorded. To the writer's knowledge, only one previous attempt has been made to bring together the known distributional data on the thrips of economic importance.[1] In view of the increased amount of attention being devoted to this order of insects it seems desirable to make available such distributional data as have accumulated.[2]

In addition to the injurious species which are recorded here, there are many others found in those immediate areas where taxonomic workers have been active, particularly New York, Florida and California. The species of economic importance, however, inevitably would come to the notice of entomologists independent of the interest stimulated in the group by systematists. As a matter of fact, it was the pear thrips that first directed Moulton's attention to the Thysanoptera. On the other hand, the presence in a state of any of the species listed below does not mean that it is injurious in that area; for example, the pear thrips is recorded from Pennsylvania but has never been a pest in that state.

The thirty-two species recorded as injurious[3] have been placed in the three

[1] S. F. Bailey, 1938. Thrips of economic importance in California, Univ. of Calif. Agr. Exp. Sta. Circ. 346, Dec., 77 pages, 39 figures.

[2] The number of references from which these data have been compiled is far too great to cite here. In addition to the Experiment Station Record, various State and Federal publications and entomological journals, private correspondence and data from slides in the writer's collection have been drawn upon.

[3] One reference, that of R. H. Pettit, 1925. Report of the section of entomology, Mich. Sta. Rpt., pp. 217–225, was overlooked when the above list was prepared. Pettit records *Leucothrips nigripennis* Reuter injuring ferns in greenhouses in Michigan.

Table 1.—Distribution of the more important thrips in the United States.

| Thrips | Ala. | Ariz. | Ark. | Calif. | Colo. | Conn. | Del. | Fla. | Ga. | Ida. | Ill. | Ind. | Iowa | Kans. | Ky. | La. | Me. | Md. | Mass. | Mich. | Minn. | Miss. | Mo. | Mont. | Nebr. | Nev. | N. H. | N. J. | N. M. | N. Y. | N. C. | N. D. | Ohio | Okla. | Ore. | Pa. | R. I. | S. C. | S. D. | Tenn. | Tex. | Utah | Vt. | Va. | Wash. | W. Va. | Wis. | Wyo. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Onion | + | + | + | + | + | + | | + | | + | + | + | + | + | + | + | + | + | + | + | | + | + | + | | | + | + | | + | + | | + | | + | + | + | + | | | | + | | + | + | + | + | + |
| 2. Greenhouse | + | + | | + | + | + | | + | | + | + | + | + | + | | + | + | + | + | + | | + | | | | | + | | | + | | | | | | | | | | | | | | | | | |
| 3. Flower | | | | + | | | | + | | | + | + | + | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 4. Gladiolus | + | + | | + | + | + | | + | | | + | + | + | | | | | | | | | | | | | | | | | | + | | | | | | | | | | | | | | | | | |
| 5. Bean | | | | + | + | + | | + | | + | | | | | | | | | | | | + | | | | | | | | | | | | | | | | | | | | | | | | | |
| 6. Pear | | | | + | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | + | | | | | | | | | | | | | |
| 7. Citrus | | | | + | | + | | + | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 8. Sugarbeet | | | | + | + | + | | + | | | + | + | + | + | + | | | | | | + | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 9. Variable | | | | + | | | | | | | | | | | | + | + | + | + | | | + | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 10. E. Grass | | | | + | | + | | | | + | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 11. Grape | | | | + | | | | + | | | | | | | | + | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 12. Cereal | | | | + | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 13. Lily | | | | + | + | | | | | | | + | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 14. Toyon | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 15. Iris | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 16. Privet | | | | | | + | | | | | + | + | | | | | | | + | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 17. Statice | | | | + | | | | + | | + | + | | + | | | | | + | + | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 18. Cacao | | | | + | | | | + | | | + | | + | | | | | + | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 19. Chrysanthemum | | | | + | | | | + | | | + | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 20. Longwinged | | | | + | | | | | | | + | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 21. Camphor | | | | | | | | + | | | | | | | | + | | | | | | + | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 22. Cuban laurel | | | | + | | | | + | | | | | | | | + | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 23. Dracaena | | | | + | | | | + | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 24. Composite | | | | + | + | | | + | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 25. Kansas wheat | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 26. Orchid | | | | + | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 27. Arizona cotton | | + | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 28. Currant | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 29. Hollyhock | | | | + | | + | | + | | | + | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 30. Plesiothrips perplexus | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 31. Echinothrips americanus | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 32. Kurtomathrips morrilli | | + | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

groups shown below. The order in which the species are listed gives a general idea of their relative importance.

Group I. Species of major importance

1. Onion thrips, *Thrips tabaci* Lind.
2. Greenhouse thrips, *Heliothrips haemorrhoidalis* (Bouché)
3. Blueberry, flower, tobacco thrips; *Frankliniella* species
4. Gladiolus thrips, *Taeniothrips simplex* Morison
5. Bean thrips, *Hercothrips fasciatus* (Perg.)
6. Pear thrips, *Taeniothrips inconsequens* (Uzel)
7. Citrus thrips, *Scirtothrips citri* (Moulton)

Group II. Species of minor importance

8. Sugarbeet thrips, *Hercinothrips femoralis* (Reuter)
9. Variable thrips, *Sericothrips variabilis* Beach
10. Eastern grass thrips, *Anaphothrips obscurus* (Müll)
11. Grape thrips, *Drepanothrips reuteri* Pr.
12. Cereal thrips, *Limothrips cerealium* Hal.
13. Lily thrips, *Liothrips vaneeckei* Pr.
14. Toyon Thrips, *Rhynchothrips ilex* (Moulton)
15. Iris thrips, *Bregmatothrips iridis* Watson
16. Privet thrips, *Dendrothrips ornatus* Jablon.
17. Statice thrips, *Haplothrips leucanthemi* (Schrank)

Group III. Species rarely injurious or reported as such very infrequently (not shown on map)

18. Cacao thrips, *Selenothrips rubrocinctus* (Giard)
19. Chrysanthemum thrips, *Thrips nigropilosus* Uzel
20. Longwinged thrips, *Scirtothrips longipennis* (Bagn.)
21. Camphor thrips, *Cryptothrips floridensis* Watson
22. Cuban laurel thrips, *Gynaikothrips uzeli* Zimm.
23. Dracaena thrips, *Parthenothrips dracaenae* (Heeger)
24. Composite thrips, *Microcephalothrips abdominalis* (D. L. Crawford)
25. Kansas wheat thrips, *Prosopothrips cognatus* Hood
26. Orchid thrips, *Anaphothrips orchidii* Moulton
27. Arizona cotton thrips, *Anaphothrips arizonensis* Morgan
28. Currant thrips, *Liothrips montanus* Hood
29. Hollyhock thrips, *Liothrips varicornis* Hood
30. *Plesiothrips perplexus* Beach
31. *Echinothrips americanus* Morgan
32. *Kurtomathrips morrilli* Moulton

The *Frankliniella* group (Number 3) includes the following species: *bispinosa* (Morgan) which is limited largely to Florida; *fusca* Hinds, found widespread over the continent; *gossypiana* Hood, restricted at present to Arizona and California; *insularis* (Franklin), known from Florida, Texas and Arizona; *moultoni* Hood and *occidentalis* (Pergande), found commonly in the far western states; *tritici* (Fitch), abundant in the central and eastern states; *vaccinii* Morgan, limited to Maine; and *williamsi* Hood, known from South Carolina and Florida.

Many of the species here listed occur elsewhere in the world but their distribution in the United States only is given in table 1.

In the accompanying map the letters (a to q) correspond with the first seventeen species found in the above table.

The apparent absence of thrips in such states as Arkansas, Oklahoma, New Mexico, Vermont, and North Dakota is undoubtedly due to the lack of published data and the scarcity of collected material from these areas. The paucity of thrips in the central states, however, does seem to be correlated with the extensive grassland area east of the Rocky Mountains which is less rich in flora than the eastern and far western states.

Some species, the onion thrips for example, with a wide host range and found throughout the continent, are not narrowly restricted by rainfall, temperature, host range, or cultural practices, although these factors may regulate their seasonal fluctuations. By contrast, the pear thrips is very limited in its distribution and often confined to very local areas, dependent upon certain moisture and temperature requirements of the soil in which it remains during the greater part of the year. The above-mentioned distribution of the *Frankliniella* species clearly shows that,

even within a genus, some species are much more narrowly limited than others. The citrus thrips is restricted almost entirely to arid, frost-free, citrus-growing areas. The greenhouse and sugarbeet thrips appear to be tropical and largely limited to greenhouses in the greater part of the United States. The toyon and camphor thrips have specific hosts, the range of which limits their distribution.

lowing harvest and the practice, in some areas, of burning the stubble.

A number of miscellaneous facts also should be pointed out. The species *Aeolothrips fasciatus* (L.) and the black hunter, *Leptothrips mali* (Fitch) have been mentioned in the literature as being injurious to apples. These species are both predacious and are therefore not plant feeders. The members of the suborder *Tubulifera*

THE DISTRIBUTION OF INJURIOUS THRIPS IN THE UNITED STATES
Mass.: a b c d h i j l o p q
R.I.: a b c d j
Conn.: a b c d f h j p
N.J.: a b c d h j o p
Del.: a b c d
Md.: a b c d f h j l o q
Legend
a. Onion thrips
b. Greenhouse thrips
c. Blueberry, flower, and tobacco thrips
d. Gladiolus thrips
e. Bean thrips
f. Pear thrips
g. Citrus thrips
h. Sugarbeet thrips
i. Variable thrips
j. E. grass thrips
k. Grape thrips
l. Cereal thrips
m. Lily thrips
n. Toyon thrips
o. Iris thrips
p. Privet thrips
q. Statice thrips

FIG. 1.—Distribution of injurious thrips in the United States.

Cultural practices and the absence of diversified agriculture, particularly in the Midwest, doubtless also contribute to the scarcity of thrips. Many species cannot become established in districts which are cultivated once or more annually, in large acreages, and limited to one crop; namely, the corn and wheat belt. In Europe, several species of thrips are serious pests of grain. One of these, *Limothrips cerealium* Hal., called the "oat thrips" in the middle west, is common in the United States. It has never become of any importance, at least in the far West, perhaps because of the long, hot, dry season fol-

are generally of minor importance (only seven of the 32 species listed are *Tubulifera*) in contrast with the suborder *Terebrantia* of which the family *Thripidae* contains nearly all the injurious species. Members of this group usually exhibit, a wide host range, great physical mobility, and a high reproductive capacity.

Therefore, it can be seen that the factors limiting the distribution of our injurious thrips vary for the species and, based on the limited information available at present, their distribution does not appear to be correlated with the Life Zones as established by Merriam.

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THE KANSAS quarantine relating to the alfalfa weevil (*Hypera postica*, Gyll.) was revised on November 15, 1939, to add to area designated as infested, Yuma County in Arizona, Larimer, Pitkin, and San Miguel counties in Colorado, Big Horn County in Montana, Morrill and Sheridan counties in Nebraska, and all Wyoming not previously designated as infested.

# The Pea Aphid on Canning Peas in Eastern Washington as Influenced by Alfalfa Plantings[1]

R. D. Eichmann, *Pullman, Washington*

Alfalfa for the control of soil erosion has come into general use in the foothills of the Blue Mountains of eastern Washington where canning peas are grown. In this region alfalfa is the principal overwintering host of the pea aphid. In 1934, a year after the canning pea industry started, the crop was severely damaged by the pea aphid although, at that time, alfalfa was not grown to any extent in the foothills. Alfalfa grown for hay production in river and creek bottoms west of the canning pea district apparently produced the aphids responsible for the outbreak. It seemed possible that the increase in alfalfa acreage under the soil conservation program might tend to make the aphid problem even more acute. Therefore it appeared desirable to collect specific data on present conditions with respect to aphid populations in order to prove or disprove this assumption.

Canning peas, in this area, are produced mainly on the flat-topped ridges of the

Fig. 1.—Pea field on a flat-topped ridge of the Blue Mountain foothills. Peaks of mountains visible in background.

Blue Mountain foothills which vary in elevation from 1,000 to 3,500 feet (Fig. 1). At lower elevations, along the creeks and rivers flowing out of these hills, especially in the vicinity of the towns of Dayton and Walla Walla and farther west, there are several thousand acres of alfalfa grown for hay. Alfalfa used for soil erosion control has been planted on the steeper slopes and in gullies of the foothills (Fig. 2), largely through the efforts of the Soil Conservation Service of the U. S. Department of Agriculture. For example, in the soil erosion control demonstration area on the Patit Creek drainage east of Dayton there was less than 100 acres of alfalfa prior to 1934 and now there is about 2,000 acres.

Fig. 2.—Alfalfa planted for soil erosion control in gullies and on a steep slope below a pea field.

The data on which the following observations are based were obtained by sweeping representative alfalfa plantings and pea fields with an insect net at frequent intervals throughout each of three growing seasons.

Early in the spring the pea aphid is found in small numbers on hay meadow alfalfa at about 1,000 feet elevation. As the season advances, in April, the aphids begin to multiply. A peak population is reached during the next month. The alfalfa is very succulent throughout this period but later it begins to mature, the stems become woody, and flower buds develop. With this change in the host plant winged aphids develop and a heavy migration occurs in a search for more succulent hosts (Fig. 3).

About the time aphids migrate from low land alfalfa, the erosion control alfalfa in the foothills has started growing and is in a succulent state. Practically no aphids are found on this alfalfa until winged migrants appear which reproduce and

[1] Published as Scientific Paper No. 419, Agricultural Experiment Station, State College of Washington.

multiply on this host for about a month. The population never reaches the density found in hay meadows. This is explained as being due to the thinner planting, less

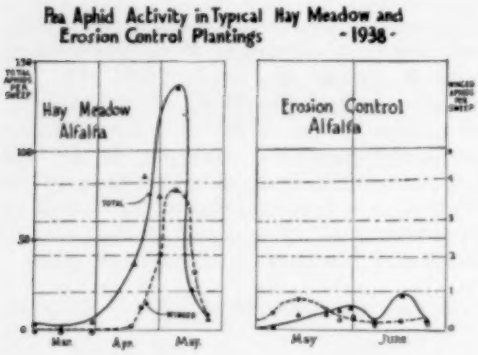


FIG. 3.—Pea aphid population in typical plantings of alfalfa.

succulent plants, drier atmosphere, and the inability of the migrating aphids to find the small scattered plantings. Usually alfalfa of this type is cut for hay once during the season. This takes place at various dates during June, depending largely on the elevation of the planting. Aphids migrate again from this alfalfa as it matures (fig. 3).

Early peas appear above ground about the time aphids are migrating from hay meadow alfalfa. Winged aphids settle on these vines even before they are tall enough to sweep with a net. This continues for a period of about 2 weeks and then winged forms drop to a minimum. Meanwhile, reproduction has multiplied the total population to a peak. The peas then develop pods, the winged aphids reappear and the population drops as migrants leave for more suitable hosts. Shortly after this time the peas are vined (Fig. 4).

The migration from early peas and from erosion control alfalfa occurs about the same time and the populations on both plantings are comparable in density. The main crop of peas is, for the most part, in a very succulent state at this time and the migrating forms settle in these fields. Because of the much greater acreage, and perhaps because of less favorable atmospheric conditions, the aphid population per unit area drops still further. As each field matures and is vined the aphids migrate to younger plantings (Fig. 4).

Near the end of the canning season the acreage has become greatly reduced through vining operations and the aphid population is concentrated in the remaining fields. It was in such fields that damage occurred in 1934 and observations show that the population builds up rapidly. The late fields are planted at the highest elevations and are often adjacent to the timber of the mountains where atmospheric conditions are probably more favorable for aphid development in late summer (Fig. 4). In an effort to escape this heavy late infestation, canners concentrate their plantings before May 15. On this account the crop must be rapidly processed; furthermore normal drouth conditions accentuate the necessity for speedy action. Comparative freedom from aphid infestation in canning peas in recent years is probably due to the elimination of late plantings and the prevalence of normal drouth conditions at harvest.

Throughout the summer, winged aphids migrate in small numbers back to alfalfa where they are barely able to sustain themselves. In August a bare minimum population occurs (Fig. 5). At that time erosion control alfalfa on steep, dry hillsides becomes so drouth stricken that it

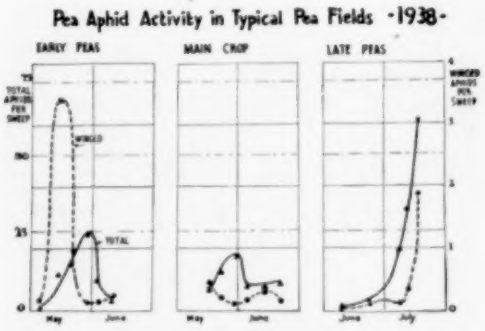


FIG. 4.—Pea aphid population in pea fields.

harbors no aphids the rest of the season. This fact, and because winged forms are found among the first aphids to appear in the spring, leads to the conclusion that erosion control alfalfa does not serve as an overwintering host.

Overwintering occurs principally on hay meadow alfalfa and the aphid population is able to build up to greater proportions in the spring on this succulent growth than at any other time. The peak of the population then shifts to erosion

control alfalfa and early peas about the last of May (Fig. 5). Since both early peas and erosion control alfalfa are available and about equally infested at this time it becomes evident that alfalfa is not essential to the migration cycle of the pea aphid during this period. In fact, early peas are apparently a more suitable host than erosion control alfalfa, as the larger fields at lower elevations, usually adjacent to hay meadows, are more accessible to the aphids. Erosion control alfalfa, however, does afford a host plant scattered throughout the district which permits the aphids to maintain themselves over a larger area and closer to the main crop of peas, to which they migrate as the alfalfa matures.

Alfalfa ceases to be a factor in aphid abundance after June. Apparently it is the concentration of aphids in the latest pea fields which builds up a population sufficiently large to cause damage in seasons favorable to outbreaks.

SUMMARY.—Hay meadow alfalfa is the chief factor in maintaining an aphid population in the canning pea district of southeastern Washington. Alfalfa grown for this purpose serves as the principal overwintering host, allows heavy populations to build up early in spring previous to migration to other hosts, and carries the late summer population.

Erosion control alfalfa, especially at high elevations, does not serve as an aphid host in any of these categories. It does, however, afford succulent host plants scattered throughout the area at the time aphids are migrating from hay meadow alfalfa. More important as host plants at this time are the large fields of early peas which are usually grown adjacent to hay meadows at lower elevations.

Both early peas and erosion control alfalfa support populations of aphids which later move to the main crop of peas. On this account erosion control alfalfa is not essential to the migration cycle and apparently it has not aggravated the pea aphid problem.

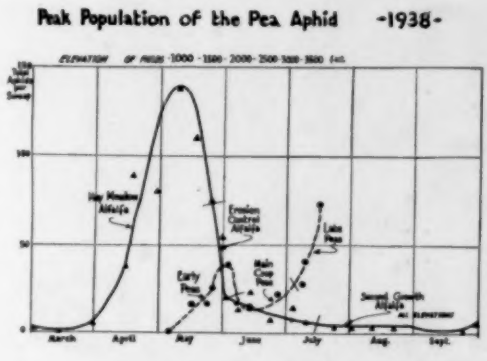


FIG. 5.—Populations in alfalfa and pea fields at different elevations. Curves based on points representing highest population on each date of observation during 1938.

# Presentation of Time-Dosage-Mortality Data by Three-Dimensional Graphs*

ROY HANSBERRY and SHIN FOON CHIU, *Cornell University, Ithaca, N. Y.*

As an aid in demonstration of the interrelationships of time, dosage and mortality in the study of insect toxicology, a three-dimensional graph has many uses. Primarily it enables one to visualize the relation between the commonly used dosage-mortality, time-mortality and time-dosage curves. Dr. Albert Hartzell of the Boyce Thompson Institute showed the writers a similar graph dealing with mortality of fungous spores, but this type of graph applied to insect mortality data has not come to our attention, although similar data has been presented in other forms. Richardson and Haas (1932) obtained and graphed time-dosage-mortality data in a series of time-dosage two-dimensional graphs.

The data illustrated were obtained by the method suggested by Dobroscky (1935) and used later by Fassig and Campbell (1937). Three arsenicals were tested, lead arsenate, calcium arsenate and calcium arsenite. Their chemical analyses were as follows: lead arsenate: 65.03 per cent PbO, 31.68 per cent $As_2O_5$

* Data from an investigation of toxicity of arsenicals supported by the Niagara Sprayer and Chemical Co., Inc.

and 0.27 per cent $As_2O_3$; calcium arsenate: 42.08 per cent $As_2O_5$ and 0.09 per cent $As_2O_3$; calcium arsenite: 5.2 per cent $As_2O_5$ and 33.1 per cent $As_2O_3$. Duplicate five-gram samples of each insecticidal

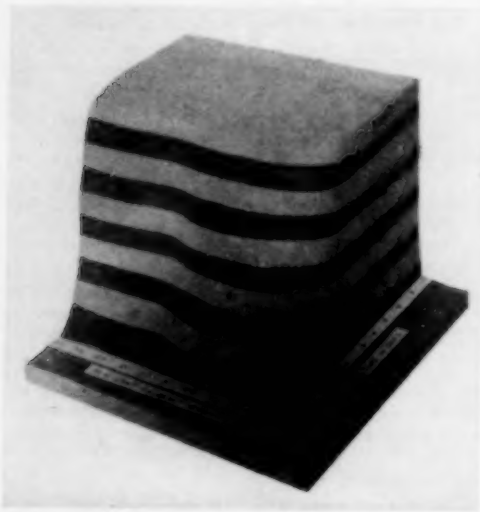

FIG. 1.—Per cent mortality (height of graph) of *Tribolium confusum* in varying concentrations of calcium arsenate in flour.

mixture were made up by weight to contain 0, 5, 10, 20, 30, 40, 60, 80, and 100 per cent of insecticide in whole wheat flour. Fifty adults of *Tribolium confusum* Duv. were placed in stender dishes each of which contained five grams of flour-insecticide mixture. Thus, each point on

**Table 1.—Per cent mortality of *Tribolium confusum* in varying concentrations of calcium arsenate in flour.**

| Per Cent Insecticide | Time in Days | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 0 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 3 | 3 |
| 5 | 3 | 7 | 29 | 40 | 66 | 94 | 99 | 100 | | |
| 10 | 9 | 19 | 47 | 73 | 98 | 100 | | | | |
| 20 | 11 | 34 | 60 | 89 | 99 | 100 | | | | |
| 30 | 13 | 37 | 78 | 96 | 100 | | | | | |
| 40 | 20 | 49 | 82 | 97 | 100 | | | | | |
| 60 | 7 | 26 | 68 | 96 | 100 | | | | | |
| 80 | 9 | 28 | 74 | 96 | 100 | | | | | |
| 100 | 6 | 32 | 79 | 96 | 100 | | | | | |

the graphs is based upon mortality among 100 insects. The beetles were sifted from the substrate daily and the dead insects removed and discarded. All tests were run simultaneously with insects selected at random from a homogeneous population. Insects from the same population, with and without food, were run as checks. The tests were carried out in darkness at a temperature of 28–29 degrees C. and a relative humidity of approximately 50 per cent.

The models were constructed of 1×10×10 inch white pine and red cedar boards glued and pressed into 10 inch cubes.

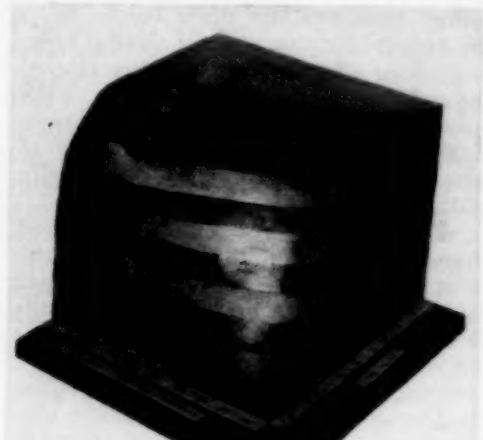

FIG. 2.—Per cent mortality (height of graph) of *Tribolium confusum* in varying concentrations of calcium arsenite in flour.

These were shaped with ordinary wood chisels and gouges according to the data given in tables, 1, 2 and 3. The thickness of each board, therefore, represents 10 per cent mortality. The models were photographed and are shown in figures 1, 2 and 3.

Several tendencies stand out from a study of these tables and figures. There was a tendency for calcium arsenate to kill more quickly than the arsenite or than lead arsenate, particularly at the

**Table 2.—Per cent mortality of *Tribolium confusum* in varying concentrations of calcium arsenite in flour.**

| Per Cent Insecticide | Time in Days | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 5 | 5 | 13 | 24 | 35 | 59 | 74 | 81 | 93 | 97 | 100 |
| 10 | 15 | 22 | 30 | 41 | 55 | 72 | 91 | 99 | 100 | |
| 20 | 31 | 47 | 59 | 72 | 83 | 94 | 99 | 100 | | |
| 30 | 39 | 58 | 77 | 91 | 97 | 98 | 100 | | | |
| 40 | 50 | 69 | 86 | 89 | 95 | 100 | | | | |
| 60 | 64 | 75 | 93 | 97 | 99 | 100 | | | | |
| 80 | 65 | 79 | 91 | 98 | 100 | | | | | |
| 100 | 68 | 89 | 100 | | | | | | | |

higher concentrations. Initial kill with lead arsenate was low but after five days it equalled or surpassed calcium arsenite in the lower concentrations; initial kills with calcium arsenite were high but the more resistant insects of the populations lived longer than those in the lead arsenate tests. With calcium arsenate and with lead arsenate there was a definite reduction in mortality with concentrations increased above 50 per cent of poison, particularly in the first few days of the experiment but there was no indication of this with calcium arsenite. Apparently the higher concentrations of the first two arsenicals were so repellent that the beetles would not feed until starved to it. The insects, however, were not starved to death, because in the checks, without food, only 2 per cent died in 4 days and after 10 days only 35 per cent were dead.

**Table 3.—Per cent mortality of *Tribolium confusum* in varying concentrations of lead arsenate in flour.**

| Per Cent Insecticide | Time in Days | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 5 | 1 | 4 | 13 | 26 | 50 | 77 | 88 | 96 | 100 | |
| 10 | 0 | 5 | 11 | 29 | 52 | 86 | 94 | 100 | | |
| 20 | 1 | 8 | 29 | 51 | 66 | 87 | 94 | 99 | 100 | |
| 30 | 9 | 46 | 64 | 76 | 86 | 96 | 99 | 100 | | |
| 40 | 7 | 53 | 71 | 84 | 94 | 97 | 100 | | | |
| 60 | 8 | 54 | 86 | 96 | 100 | | | | | |
| 80 | 28 | 56 | 74 | 91 | 98 | 100 | | | | |
| 100 | 19 | 43 | 72 | 89 | 95 | 100 | | | | |

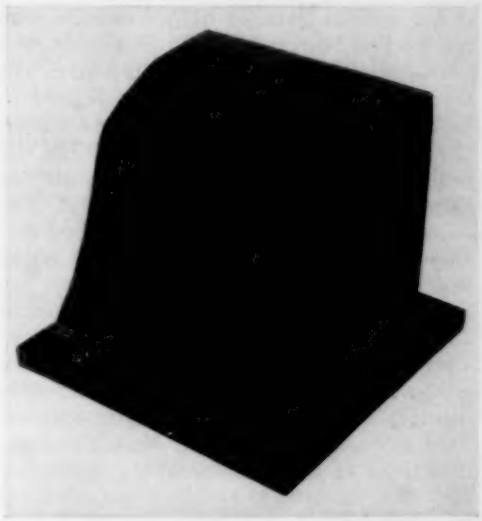

FIG. 3.—Per cent mortality (height of graph) of *Tribolium confusum* in varying concentrations of lead arsenate in flour.

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# Some Entomological Observations in California

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There are many factors which determine whether or not a given insect will be destructive. Many of these are quite obvious, while others are extremely difficult to determine. Probably the most important contribution that can be made in economic entomology is determining complete life histories under natural conditions and noting with extreme care and accuracy population trends over a period of years. If sufficient knowledge can be obtained concerning the insect in relation to its environment, control in many cases can probably be very much simplified. Modification of some farm practice may be sufficient to eliminate serious damage by certain insects. There are many examples in the literature where thorough life history studies have led to satisfactory control of insects. This paper merely points out several interesting observations on size of plantings and host preference that have influenced the damage done by insects to several important agricultural crops.

Near San Jose, *Diabrotica soror* Le Conte for the past several years has seriously damaged the pole bean crop which was grown for the fresh market and canning. The individual plantings were usually small, and the Diabrotica beetles became concentrated in these areas, often

doing serious damage before harvest was complete. During the 1938 season the beetle was not nearly as destructive, yet from general observations it appeared to be as abundant, if not more so, as during the preceding few years. In 1938, in the region in question, there were a number of large plantings of baby lima beans. The beans were harvested green, shelled and frozen for fresh consumption. The growing and maturing lima bean plants appeared to be as attractive to *D. soror* as the pole beans, and as a result the population that would ordinarily have been concentrated in the pole beans was greatly diluted, and no serious damage occurred. It appeared quite certain that the large plantings of baby limas were responsible for the relatively small population of beetles on the pole beans.

CORN EARWORM.—The corn earworm, *Heliothis obsoleta* Fab., appears to prefer corn and beans to tomato. At least in the northern tomato-producing section of California the tomato crop does not usually become seriously infested until rather late in the season. The most serious damage is done after the corn and bean crops have reached maturity. It appears that during the time that these crops are in a suitable stage of growth to be attractive to the egg-laying moths, tomatoes are not in danger of being seriously attacked. However, later, after these crops have dried up, there is some danger that the moths which emerge in these fields will fly to the tomatoes and set up severe infestations. Although the presence of the preferred host unquestionably reduces the corn earworm population in tomato fields early in the season, this benefit may be offset later in the year by a heavy migration of moths from the fields in which the preferred hosts were grown to the tomatoes. If the preferred hosts were not grown and there were no moths migrating from a great distance, it is very likely that corn earworm infestation in the tomato fields for the entire season would be less than where preferred hosts are grown in abundance.

HORNWORMS.—Hornworms seriously attacked a fall crop of potatoes in the agricultural area adjacent to Madera. The potato acreage was rather limited but of considerable importance because, if good quality and yields could be obtained, it was expected that the region would develop into an important potato-producing section. Several rather heavily infested fields were examined, and it was evident that the moths which set up the infestation must have moved in from the outside. Within the region datura was found in abundance and unquestionably was the plant on which the hornworm population had built up. I am unable to say whether potato plants are preferred to datura, but, at the time our examinations were made (September 26 and October 6) the infestation in the potato fields was much greater. If fall potatoes really become an important farm crop in this area, it is very likely that the hornworm problem will become less, as the potato acreage increases, because it is quite evident that the hornworms population built up on the wild datura, and as the potato acreage increases, the number of moths produced on the datura will not be large enough to infest a large potato planting seriously. The larger the potato acreage the greater the dilution will be. Because of the lateness of the infestation on potato, it does not seem possible that there can be any build-up on this crop. The seriousness of the infestation is, therefore, almost wholly dependent upon the moth population that has developed on the wild datura.

The examples cited above are only a few of a number that might be given but serve to illustrate the need for knowing the exact conditions under which crops are grown. They tend to serve in part as explanations of some of the puzzling situations that confront us at times. Certainly, as our entomological knowledge is increased, we should be able to plan a cropping schedule for a given district that would materially lessen the danger of certain insects becoming unduly destructive. It is recognized that the crops grown are largely influenced by economic conditions, but if it can be definitely shown that a certain crop sequence is likely to result in serious losses from insects, little difficulty should be encountered in persuading farmers to choose another combination.

Chemicals should be resorted to last as a means of controlling insects. This is particularly true of those materials that leave a poisonous residue on the products to be protected and that add a toxic element to the soil. Control should be directed along the lines of crop manage-

ment, cultural practices, development of resistant varieties, introduction of new parasites and predators, avoiding practices that unfavorably affect the native parasites and predators, planting crops at a time when they are likely to be least seriously attacked, and the proper selection of crops. The most important factor in obtaining these ends is a more thorough knowledge of the insects with which we have to deal and of the details of their environment.

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# Experiments with Pyrethrum for the Control of Codling Moth (*Carpocapsa pomonella* L.)

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The use of pyrethrum for codling moth control has been investigated by Yetter (1928), Headlee, Ginsburg & Filmer (1930), Spuler, Dorman & Gillies (1931), Eyer & Crawford (1932), Gillies (1932), Haegele (1933),† Webster, Marshall, Miller & Hansberry (1933), Childs (1934), Headlee (1934), Webster & Marshall (1934), Worthley (1934), Boyce (1935), Maercks (1935), Schoene & Jefferson (1935), Thompson, (1935),† McGovran (1936), Eyer (1938), and others.

None of these investigations resulted in satisfactory control of codling moth with pyrethrum and pyrethrum insecticides are not now in commercial use against codling moth. In most of these experiments, extracts of pyrethrum in alcohol, acetone or kerosene were used in conjunction with summer oil sprays containing one-half to 1 per cent of oil, substituting one or more such oil-pyrethrum sprays for the regular lead arsenate cover sprays. In general, control was not as good as with lead arsenate and the cost of pyrethrum was higher. Worthley (1934) found pyrethrum-soap spray ineffective. Boyce (1935) obtained unsatisfactory results with pyrethrum on codling moth in Persian walnuts. Thompson (1935)† failed to get control with a solution of pyrethrins in deodorized kerosene applied as a fog or mist.

According to Maercks (1935), an aqueous suspension of pyrethrins caused high mortality to codling moth eggs, but Schoene and Jefferson (1935) concluded that rather high concentrations of pyrethrins were necessary in summer oil sprays to give additional ovicidal action. McGovran (1936) found ground pyrethrum in summer oil only moderately toxic to newly hatched larvae.

The development of newer types of pyrethrum insecticides, within the last few years, accurately standardized and stabilized as to pyrethrin content, has made possible the commercial control of insects against which pyrethrum was formerly not used. It has been proved repeatedly, for example, that a new type of pyrethrum dust,* when diluted with talc to a pyrethrin content of 0.2 per cent, is more effective than powdered pyrethrum flowers containing 0.9 per cent pyrethrins.

It was believed that this type of pyrethrum insecticide might be of value in codling moth control, either in conjunction with other types of pyrethrum insecticides, or with some of the materials which are now in commercial use. It was also considered possible that some progress might be made in codling moth control by attacking the over-wintering larvae with pyrethrum. Accordingly, arrangements were made for comprehensive tests, under commercial conditions, in a locality heavily infested by codling moth. The following is a preliminary report on these experiments.

EFFECT OF PYRETHRUM ON OVER-WINTERING LARVAE.—For a period of about five months, in the winter, all of the codling moths in an orchard are present in one stage—the over-wintering larval stage. This would seem to be an ideal time to reduce infestations, if some efficient method could be developed for killing the larvae, which are spun up in water-resistant, silken cocoons. It is well known that the oil or lime-sulfur dormant

* Early publication of this paper has been secured by the payment of the printing charges.

† Unpublished report.

* U. S. Patent 2,092,308.

sprays customarily used in apple orchards have little or no effect on the larvae. For example, when over-wintering larvae were removed from their cocoons and sprayed with 3 per cent dormant oil emulsified with ammonium oleate, at 350 pounds pressure, only 16 per cent died; the others pupated and emerged as moths.

The addition of an oil-pyrethrum extract to the dormant oil, so that the latter had a pyrethrin content of 0.2 g. per 100 cc., increased the kill to only 44 per cent, under the same conditions. The use of a sulfated alcohol emulsifier instead of ammonium oleate did not give appreciably higher kills.

**Table 1.—Effect of kerosene and pyrethrum-kerosene on codling moth larvae.**

| PYRETHRIN CONTENT MG. PER 100 CC. | LARVAE KILLED IN 24 HRS. PER CENT |
|---|---|
| 0 | 0 |
| 40 | 75 |
| 60 | 100 |
| 80 | 100 |
| 100 | 100 |

A commercial-soap insecticide,* containing 1.4 g. of pyrethrins per 100 cc. was diluted 1 to 400 with water and sprayed on larvae and pupae which were removed from their cocoons. The kill of larvae was 86 per cent; of pupae, 67 per cent. When a similar dilution was applied to tree trunks, under 700 pounds pressure, most of the larvae contacted were killed but the spray failed to reach and penetrate many cocoons, even under this high pressure. After numerous experiments the idea of using an aqueous spray was abandoned because adequate penetration could not be obtained.

Codling moth larvae were removed from their cocoons and placed on a screen where they were sprayed with kerosene, and pyrethrins in kerosene, using a hand sprayer held at a fixed distance from the screen. The results are shown in table 1.

Unless heavily sprayed, kerosene has little effect on codling moth larvae, but when pyrethrins are added to the kerosene, the kill is greatly increased.

Application of a pyrethrum-kerosene spray, containing 60 mg. pyrethrins per 100 cc., to the trunks of Jonathan trees in July, at 20 lbs. pressure, gave 99 per cent kill of larvae and 97 per cent kill of pupae under the bark. The insecticide apparently penetrated wherever larvae could go and easily wetted the cocoons, killing larvae and pupae.

It would seem obvious that application of a pyrethrum-kerosene spray to an entire apple tree would result in serious injury to foliage and fruit or to foliage buds and fruit buds even if applied to a dormant tree especially as it is necessary to wet the hibernating places thoroughly. Application as a fine mist, or fog, will not penetrate the hibernating places or the cocoons; in fact, even fumigants will not penetrate unless very high concentrations of gas are used. It was believed, however, that by scraping the upper portions of the tree to remove hibernating places (or hibernating larvae), leaving the first 4 to 8 feet of trunk and leaders unscraped, the population could be concentrated in the unscraped trunk and leaders, which could then be sprayed without injury to the tree. Before the actual efficiency of such a control program could be determined, however, it was necessary to find out what proportion of the over-wintering larvae hibernate in the trees.

HIBERNATING HABITS OF CODLING MOTH LARVAE.—In the Wenatchee District, where these experiments were conducted, the belief is widely held among growers that a considerable proportion of the over-wintering larvae spin up in the ground or in the cover crop. It is also widely believed that complete scraping of the trees tends to drive more of the larvae into the ground. This, in turn, is thought to prolong the emergence period of the moths in the spring, thereby rendering control much more difficult. In 1939 the spring emergence period lasted more than 60 days.

Experiments on the hibernating habits of codling moth in the Wenatchee District were carried out in three orchards known to be heavily infested. Three varieties of apple trees were used and in most cases a complete record of the number of thinnings, drops, wormy and sound apples was kept. Counts of the over-wintering larvae were made from 1 to 7 days after harvest and drops were left on the ground until the day the counts were made. The trees were carefully scraped and examined from the top to 12 in. below

* *Multicide.*

ground. The cover crop, including soil to a depth of 6 to 12 in. was also thoroughly searched. Soil was sifted through 3 sieves, 1 foot by 2 feet, having one-half inch, one-fourth inch and one-sixteenth inch mesh wire. The material remaining on the one-sixteenth inch screen was spread on a 4 foot by 4 foot canvas where the larvae were easily found. The sandy-loam soil sifted readily and the larvae were not killed by this treatment.

The results of these experiments are given in table 2.

In figure 1 the areas investigated are shown diagrammatically. The 8 foot by 9 foot by 6 inch segment was examined only under tree No. 3; the 2 foot by 2 foot by 12 inch sections of soil were examined under trees No. 1, 2 and 4; the circular area was examined under all four trees.

In trees No. 1 and No. 2, which had not been scraped, more than 97 per cent of the worms had spun their cocoons under the bark of the tree. In the young tree (No. 1), the bark of the upper branches was quite smooth and most of the larvae were in the lower third; 8.3 per cent were in the bark less than 3 inches below ground. In the old tree (No. 2), 57.8 per cent of the larvae were in the middle third, with 0.6 per cent in the bark below ground.

The upper two-thirds of tree No. 3 had been scraped in June, leaving the bark unscraped on the lower third. More than 98 per cent of all larvae found were

**Table 2.—Hibernation of codling moth larvae, Wenatchee district, October 1939.**

| TREE NO. | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Variety of apple | Gold. Delicious | Jonathan | Jonathan | Delicious |
| Age of tree, years | 15 | 30 | 30 | 35 |
| Control program summer 1939 | Not sprayed Not scraped | 11 lead sprays Not scraped | 5 oil sprays, 20 pyrethrum dusts. Upper ⅔ scraped in June. Lower third not scraped | 9 lead sprays Scraped in April to ground-level |
| Number of hibernating larvae | 72 | 329 | 308 | 138 |
| Distribution of over-wintering larvae: | | | | |
| Per cent in tree: | | | | |
| Upper third | 0.0 | 19.1 | 15.3 | 19.6 |
| Middle third | 11.1 | 57.8 | 13.6 | 35.5 |
| Lower third | 77.8 | 20.4 | 69.5 | 21.0 |
| Below ground 0″ to 3″ | 8.3 | 0.6 | 0.0 | 5.1 |
| Below ground 3″ to 12″ | 0.0 | 0.0 | 0.0 | 0.7 |
| Total in tree | 97.2 | 97.9 | 98.4 | 81.9 |
| Per cent in soil: | | | | |
| 0″ to 8″ from tree: | | | | |
| 0″ to 3″ deep | 0.0 | 0.6 | 1.6 | 0.7 |
| 3″ to 12″ deep | 1.4 | 0.0 | 0.0 | 0.0 |
| 8″ to 24″ from tree: | | | | |
| 0″ to 3″ deep | 0.0 | 0.3 | 0.0 | 0.7 |
| 3″ to 12″ deep | 0.0 | 0.0 | 0.0 | 0.0 |
| 24″ to 132″ from tree: | | | | |
| 0″ to 6″ deep | 0.0 | 0.0 | 0.0 | 0.0 |
| 6″ to 12″ deep | 0.0 | — | 0.0 | 0.0 |
| Total in soil | 1.4 | 0.9 | 1.6 | 1.4 |
| Per cent in cover crop: | | | | |
| Blue grass | 0.0 | — | — | 0.0 |
| Alfalfa | — | 0.0 | 0.0 | 2.9 |
| Pigweed | — | 0.0 | 0.0 | — |
| Foxtail | — | 0.0 | 0.0 | — |
| Total in cover crop | 0.0 | 0.0 | 0.0 | 2.9 |
| Per cent in debris on ground | 1.4 | 1.2 | 0.0 | 13.8 |

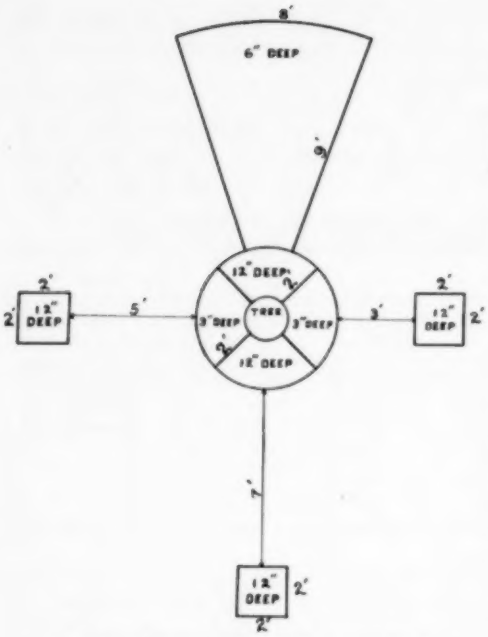


FIG. 1.—Diagram of soil areas examined for over-wintering larvae.

in the tree, with 69.5 per cent in the unscraped lower third and none in the underground bark.

No larvae were found in the cover crops under any of these three trees. The cover crops consisted of alfalfa, blue grass, pigweed and fox-tail. Out of a total of 709 larvae found in and under these three trees only nine, or 1.2 per cent, were found in the soil, all but one within 3 inches of the surface. Five larvae (0.7 per cent) were found in loose bark near the bases of the trees.

Although tree No. 4 had been thoroughly scraped to the ground level in April, there were still sufficient hibernating places to shelter 81.9 per cent of the population, with 5.8 per cent in the underground bark. Only under this tree were larvae found in the cover crops; 2.9 per cent had entered the broken stems of alfalfa. The percentage in the soil under this tree was only 1.4 per cent, but 13.8 per cent had spun up in loose bark and trash at the base of the tree.

It is clear that larvae prefer to hibernate under the bark of the tree. Few larvae were found on small limbs with smooth bark excepting in crotches, cracks or pruning scars. By scraping the upper two-thirds of a tree the larvae can be concentrated in the bark of the lower third of the tree. Scraping the entire tree tends to

FIG. 2.—Scraped tree, with rough bark left unscraped from white lines on leaders to ground.

drive the larvae into the cover crop and into debris near the base of the tree. The proportion of larvae hibernating in the soil is negligible. None of the larvae found in the soil was in a cocoon.

A NEW METHOD FOR CONTROL OF OVER-WINTERING CODLING MOTH LARVAE.*—As soon as all of the crop has been harvested, remove all apples from the ground, including drops, and destroy them. Remove all props, boxes or other material that may shelter larvae. Scrape the upper two-thirds of the tree carefully to remove all hibernating places and hibernating larvae. Most of the larvae will be killed by the scraper, but a tarpaulin should be placed under the tree to catch the scrapings and these should be burned. Leave from 4 to 8 feet of the trunk and leaders unscraped, depending on the size and age of the tree. Figure 2 shows a 30 year old White Winter Pearmain scraped to within 7 feet of the ground (marked by the white lines on the leaders).

Wait about 3 days after scraping, so that any larvae migrating to the tree may reach it, and spray the rough bark left on the trunk and leaders with a solution of pyrethrins in kerosene containing 60 milligrams of pyrethrins per 100 cc. A small portable sprayer (2 to 3 gal.), with hand-operated pump, is satisfactory, as 20 to 30 pounds pressure is sufficient. Wet the trunk and leaders thoroughly and spray the loose bark and trash on the ground within two feet of the trunk. Do not use a nozzle throwing a fine mist or fog, or let the solution strike the other parts of the tree.

The second year it will not be necessary to scrape the upper two-thirds again. Instead, after pruning, the oil-pyrethrum spray is applied to pruning scars, crotches and cracks in the upper two-thirds with a pressure oil can. With a little experience the hibernating places are easily recognized. A satisfactory oil-can is the one-quart *Golden Rod* oiler, model 34, made by F. Jaden Mfg. Co., Hastings, Nebr. (fig. 3). This oiler delivers the insecticide to the spot desired, without danger of hitting leaf buds or fruit buds; it holds sufficient solution to treat a large tree.

The rough bark on the trunk and leaders must, of course, be sprayed each year.

* A patent on this method of control is pending.

This method was used on a block of 72 trees, which were two-thirds scraped after harvest and then sprayed on trunks and leaders. It was also applied to a block of 93 trees which were scraped (upper two-thirds) in June and sprayed on trunk and leaders after harvest, treating the upper two-thirds with the pressure oiler. A typical count of an entire tree from the latter block is shown in table 3.

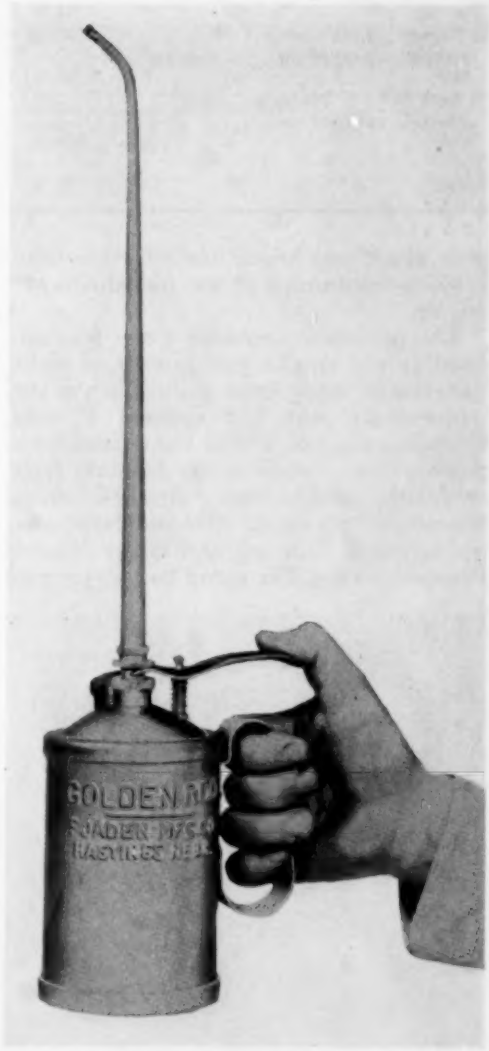


FIG. 3.—Oiler used for applying pyrethrum-oil spray for control of over-wintering larvae.

This control can be improved by delaying the use of the oiler until the leaves are off and the trees are pruned. The twelve live larvae were found in places which had been missed by the oiler. Kero-

**Table 3.—Effect of pyrethrum-oil spray on over-wintering larvae.**

| LOCATION OF LARVAE IN TREE | DEAD | ALIVE | KILL PER CENT |
|---|---|---|---|
| In upper two-thirds, scraped in June, treated with oiler in Oct. | 22 | 12 | 64.7 |
| In lower third, not scraped, sprayed in Oct. | 68 | 0 | 100.0 |
| In bark 0″ to 3″ below ground, sprayed in Oct. | 2 | 0 | 100.0 |
| Totals | 92 | 12 | 88.4 |

sene alone was much less effective than kerosene containing 60 mg. pyrethrins per 100 cc.

The pyrethrin-kerosene spray was applied to the trunks and leaders of eight varieties of apple trees in July, when the temperature was 112 degrees F. and humidity was low. Under these conditions there was no visible injury to bark, fruit or foliage of Delicious, Red Delicious, Jonathan, Stayman, Golden Delicious, Spitzenburg, Winesap and White Winter Pearmain trees. The spray had no permanent repellent action to codling moth larvae, as many over-wintering larvae were found under the bark of these trees after harvest. There was also no visible injury to the blocks of 72 and 93 trees sprayed in the fall. The effect of the pyrethrin-oil spray on leaf buds and fruit buds of dormant trees is being investigated further.

The same spray can be used to advantage on prop piles, boxes, packing sheds and other places where larvae hibernate. Figure 4 shows a prop pile designed to facilitate spraying. Larvae frequently spin up in the ends of the props before these are removed from the trees.

The average cost per tree per year for 30 year old trees, including five varieties, was 68 cents. This included labor for scraping, oiling and spraying as well as the cost of the insecticide.

PYRETHRUM DUSTS FOR CODLING MOTH CONTROL.—Pyrethrum dusts are toxic to adult codling moths, newly hatched larvae and mature larvae. In laboratory tests, a dust containing 0.1 per cent pyrethrins applied to adult moths killed 91 per cent in 6 hrs. A dust containing 0.2 per cent pyrethrins killed 100 per cent in 18 hrs;

FIG. 4.—Props piled to facilitate spraying for over-wintering larvae.

under similar conditions, a dust composed of 1 per cent dinitro-ortho-cyclohexylphenol in walnut shell flour gave 30 per cent kill and a cubé dust containing 0.96 per cent rotenone and 4.3 per cent ether extractive killed only 19 per cent. Newly hatched larvae placed on foliage previously dusted with the pyrethrum dust (0.2 per cent pyrethrins) died within 2 hours. When mature larvae were dusted with the pyrethrum dust (0.2 per cent pyrethrins), 100 per cent died in 24 hours. Under the same conditions, the dinitro dust killed 23 per cent and the cubé dust 71 per cent of mature larvae.

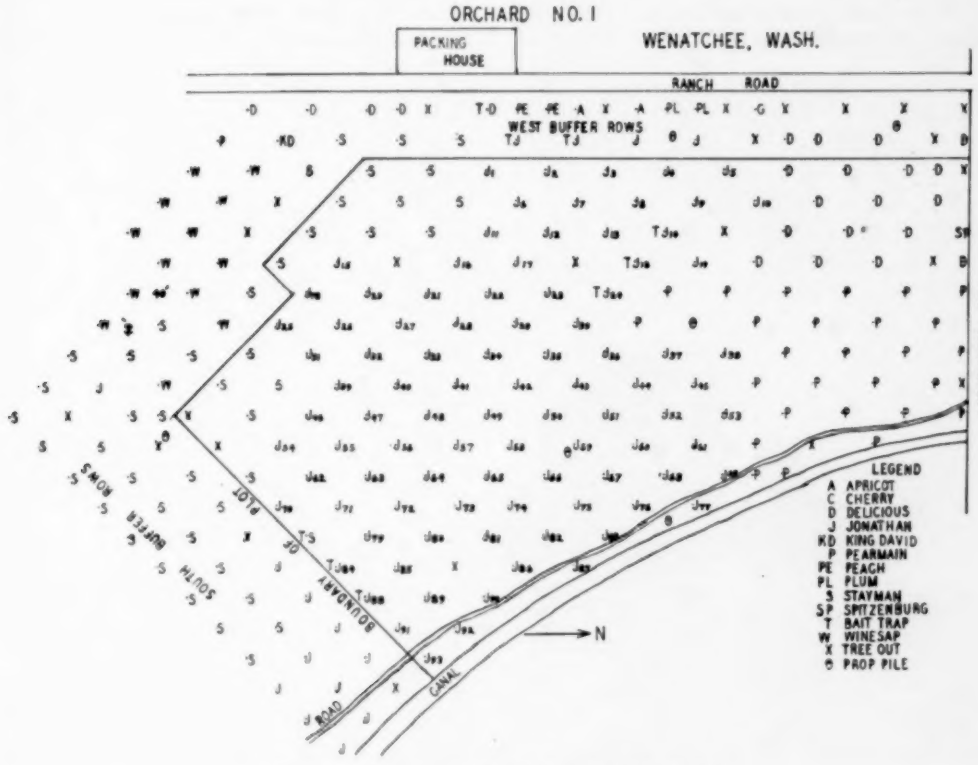


FIG. 5.—Map of experimental orchard dust plot.

Experiments designed to control the adult moth population obviously cannot be carried out on small plots of a few trees because of migration. It was necessary, therefore, to obtain several acres of orchard, in order to try the dust on a commercial scale. An orchard was finally selected 2 miles from Wenatchee, probably the most heavily infested locality in the United States. The set of fruit on the trees was so light that the owner had decided not to try to raise a crop. No dormant spray had been applied for two years. There was a packing house on the west side and another on the north side of the orchard, 30 to 50 feet from the trees. The experimental plot consisted of 93 Jonathan trees, thirty years old; to the north of the Jonathans were Delicious trees and 27 Pearmain trees from which the blossoms had been picked; to the south were Stayman and Winesap trees and, at a distance of 150 yards, more Jonathan trees with a good set of fruit which the owner intended to spray with lead arsenate in the usual way, and which therefore served as a check or control on the dusted plot. A map of the experimental plot is shown in figure 5.

The infestation the preceding year had been very heavy; the Jonathans near the packing shed on the west side had run 40 to 50 per cent culls at harvest. There was also a heavy reduction in grade because of stings, only 26 per cent of the Jonathans being extra fancy grade. It is, of course, well known that the Jonathan

is one of the varieties most susceptible to codling moth attack. With such unfavorable conditions, it was felt that this orchard would provide a thorough test for any control program, especially as the flight of moths during the period of the tests was the heaviest on record in Wenatchee Valley.

The dust used was made from *Dry Pyrocide*, which is a concentrate composed of an oil solution of pyrethrins mixed with diatomaceous earth, standardized to contain 2 per cent pyrethrins and stabilized with an antioxidant. The finished dust, known as *Pyrocide Dust*, consisted of 10 per cent *Dry Pyrocide* and 90 per cent talc and contained 0.2 per cent pyrethrins. The dust was applied at the rate of about 2 lbs. per tree, by means of a special orchard duster made by Master Fan Corporation, Los Angeles, California (figure 6). The trees had a spread of about 30 feet and were 20 to 25 feet high; they were planted in rows about 29 feet apart.

FIG. 6.—Duster used for applying pyrethrum dust.

PRELIMINARY REPORT ON COMMERCIAL APPLICATION OF PYRETHRUM DUST.—Pyrethrum dust, applied to the orchard, proved to be very effective against adult moths. Sheets (30 by 30 feet) were placed under some of the trees and counts were made of the number of codling moths and other insects knocked down by the dust. The moths began to fall on to the sheets 3 or 4 minutes after the dust was applied; after one hour, the knockdown was practically complete. The moths that were knocked down were placed in a sleeve cage and suspended over an apple branch so that the kill could be determined. The average kill of moths knocked down was 96 per cent, after 18 hours; these moths were almost equally divided between the sexes, 50.2 per cent being males and 49.8 per cent being females. The maximum number of moths knocked down from a single tree by one application of dust was 41.

Best results were obtained when dust applications were made at about 4 A.M. At that time the moths were inactive and did not fly from the trees as the duster went by; the air was also more calm in the early morning than in the evening. Applications made at 7 P.M. to 9 P.M., when moths are most active, caused many moths to fly away as the duster ap-

proached. There was also more movement of the air in the evening, so that the dust drifted out of the orchard to some extent.

Newly hatched larvae were readily killed by the dust, which appeared to remain toxic to them for about 24 hours after application, even at high temperatures and in fairly bright light.

Mature larvae, which had left the apples and were seeking places to pupate, were also knocked down on to the sheets by the dust. These larvae were placed in a ventilated can containing pieces of corrugated paper in which some spun cocoons; the can was placed in a shady tree-crotch. Only 22 per cent of the larvae knocked down pupated and emerged as moths; 69.5 per cent died in the larval stage and 8.5 per cent in the pupal stage. The maximum number of larvae knocked down from a single tree by one application of dust was 19.

The effectiveness of the dust was augmented by the use of oil sprays. These not only had considerable ovicidal action, but also helped to control mite infestations. The oil was a medium oil, 92 per cent unsulfonatable residue; it was used at concentrations of one-half per cent to three-fourths per cent. These oil sprays were applied in the usual manner, between dust applications.

Bait-traps were hung in the dusted plot and, in the Jonathans, in the plot which the owner sprayed with lead arsenate. Counts of the moths trapped were made daily.

The pyrethrum dust-oil spray program caused a marked reduction in the number of moths caught in the bait-traps. This is graphically shown in figure 7, where the catch of moths in the dusted plot is compared with the catch in the plot sprayed with lead arsenate.

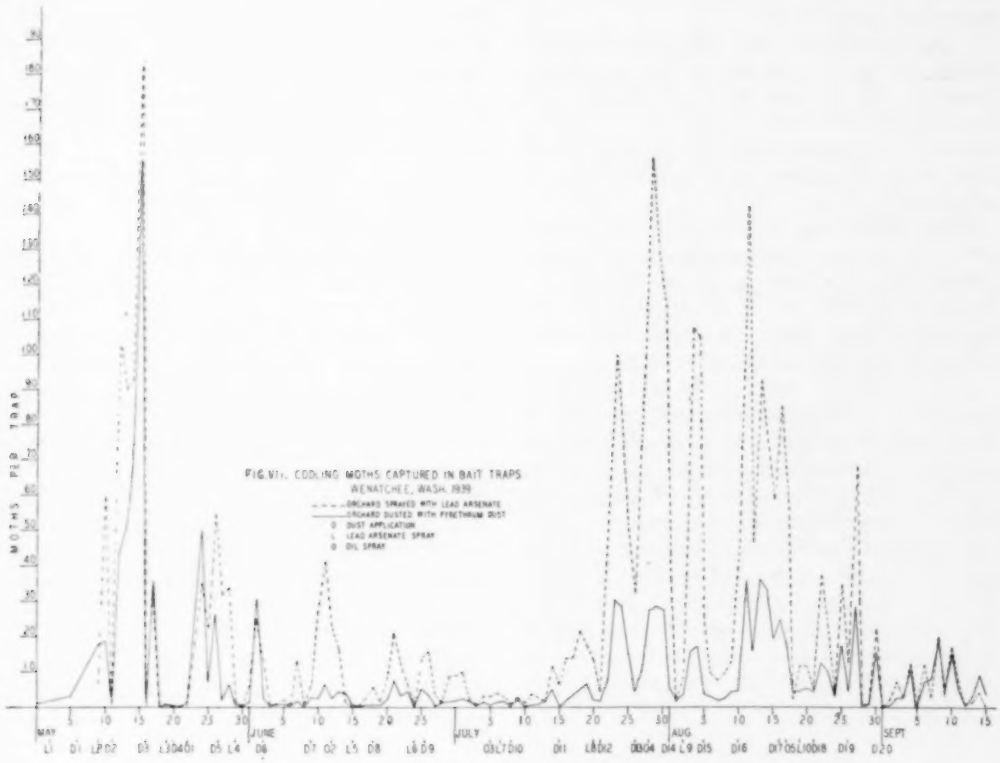


FIG. 7.—Codling moths captured in bait-traps, Wenatchee, Wash., 1939.

A patent on the essential features of this method of control is pending.

The dusted plot received a calyx spray and one cover spray of lead arsenate, 20 applications of dust, and 5 oil sprays. It should be noted, however, that the experiment was started with no knowledge of how the materials would work, or how

they should be applied. For example, nearly all of the dust applications for the first brood were made in the evening; later, it was discovered that early morning applications were more effective. It is believed that the lead arsenate cover spray was unnecessary.

The lead arsenate plot received a calyx spray and 11 cover sprays; ten of the cover sprays contained 3 lbs. of lead arsenate and one-half gallon to 1 gallon of mineral oil per 100 gallons of spray. Each application required about 65 gallons of spray per tree.

Careful counts were made of all thinnings, drops and picked fruits to determine the percentage of stings and wormy apples. There was little difference between the dusted plot and lead arsenate plot so far as thinnings and drops were concerned.

The apples harvested from the dusted plot contained approximately the same proportion of wormy apples as those from the lead arsenate plot; the dusted apples, however, had only one-fifth as many stings as the lead-sprayed apples.

The apples in the dusted plot matured somewhat earlier than those sprayed with lead arsenate. The color of the dusted apples was excellent, 70 per cent being extra fancy grade. The Jonathans from the lead arsenate plot were only 20 per cent extra fancy grade. When wiped, the dusted apples were below the Federal tolerance for lead and arsenic; it was not necessary to wash them. The apples sprayed with lead arsenate required an alkaline wash (6.7 per cent sodium silicate) at 100 degrees F. followed by an acid wash ($1\frac{1}{4}$ per cent HCl) at 90 degrees to meet the federal tolerance.

The cover crop in the dusted plot was better than in the lead arsenate plot. Moreover, it contained no poison, unless arsenic and lead were absorbed from the previously contaminated soil. The *Pyrocide Dust*-oil spray program can be used without danger to orchard workmen or to domestic animals in the orchard. The latter fact may prove to be important in orchard sanitation.

In addition to codling moths and their larvae, the following insects were found dead on the sheet after dusting: buffalo treehoppers, rosy aphids, leaf roller larvae and species of Lygus. European red mite, Pacific mite and scale were not appreciably affected by the dust.

*Pyrocide Dust* is compatible with copper compounds, sulfur, nicotine and certain other insecticides.

The experiments are being continued on a commercial scale, combining the control of over-wintering larvae with the dust-oil program. It is hoped to present a more complete report after another season's work.

SUMMARY.—Experiments with pyrethrum for control of codling moth have been described, including the use of pyrethrin-oil spray for controlling pupae and over-wintering larvae and the use of pyrethrum dust, in conjunction with oil sprays, for control of adult moths, eggs, newly-hatched larvae and mature larvae. Thus the codling moth is attacked in every stage of its life history.* 1–6–40.

* The authors wish to express their appreciation to Mr. Earl V. Mac Phail, Wenatchee, for valuable assistance in conducting these experiments.

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# A New Machine for Turf Dusting and Hairy Chinch Bug Control*

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During the past two summers numerous infestations of the hairy chinch bug, *Blissus hirtus* Montadon, in turf on Long Island have been brought to the attention of the writer. Recommendations for control based on the experiments of MacLeod and Maxwell (1937) have proven uneconomical from the standpoint of the amount of material applied, number of applications, and effectiveness of applications. Applications were ineffective in most cases because the method of applying the insecticide was inefficient.

MacLeod and Maxwell (1937) and Hamilton (1935) found that dusts were more effective than sprays against the chinch bug. However, MacLeod and Maxwell (1937) have shown that a heavy application, 25 lbs. per 1,000 square feet, of a one per cent tobacco dust or a one per cent rotenone dust is necessary in order that the chinch bugs might be reached and killed. They recommended that the dust be distributed with a lime-spreader. This made the use of heavy applications, and raking in, necessary for effective control. It was apparent that a device which would force dust evenly and quickly into the grass would be essential to any practical control.

In collaboration with Mr. Fred J. Faulkner of the Nassau Grain Co., Roslyn Hts., L.I., a turf dusting machine[1] was designed which meets practically all the requirements necessary for applying dusts effectively and economically (Fig. 1). This new machine is the outgrowth of a machine somewhat similar in operation which Mr. Faulkner has been using in his commercial chinch bug control work for the past two years. Although the older machine had several disadvantages, its distribution of dusts was nevertheless far superior to any method of application previously recommended. The much simpler and more effective type of machine was devised through the use of some of the unique features[2] of the older machine in combination with the Messinger wheelbarrow 4-nozzle duster.

Each of the four flexible outlet ducts leads to a wide dust nozzle which is set into the front end of an aluminum sled approximately two feet square. At the posterior end of this sled a wide nozzle is attached to a duct which leads to the air intake opening of the duster. This device functions as a vacuum return which draws some of the waste dust back into the air stream to be used over again. This vacuum return and the cloth fringe on the sled help prevent dust wastage and dust cloud formation. The machine gives a light, penetrating, and even distribution of dust in a path two feet wide. The sled is adjustable in all directions. This makes possible the even and quick dusting of spinach, strawberries, and other low-growing plants.

Although no actual insect control experiments have been run with this machine, test applications with various dusts proved it to be superior to the older machine. It is capable of applying dusts evenly and with force up to approximately 600 pounds per acre. By the easy removal of the sled and the attachment of dust nozzles to each of the four flexible ducts, the machine can be quickly restored to its original use as a row-crop duster.

With the kind permission of the authorities of the Beth Page Golf Course

* Contribution from the Plant Protection Laboratory, State Institute of Agriculture, Farmingdale, L. I. Early publication of this paper has been secured by the payment of the printing charges.

[1] This machine will appear on the market early this spring.

[2] Patents Pending to Mr. Fred J. Faulkner.

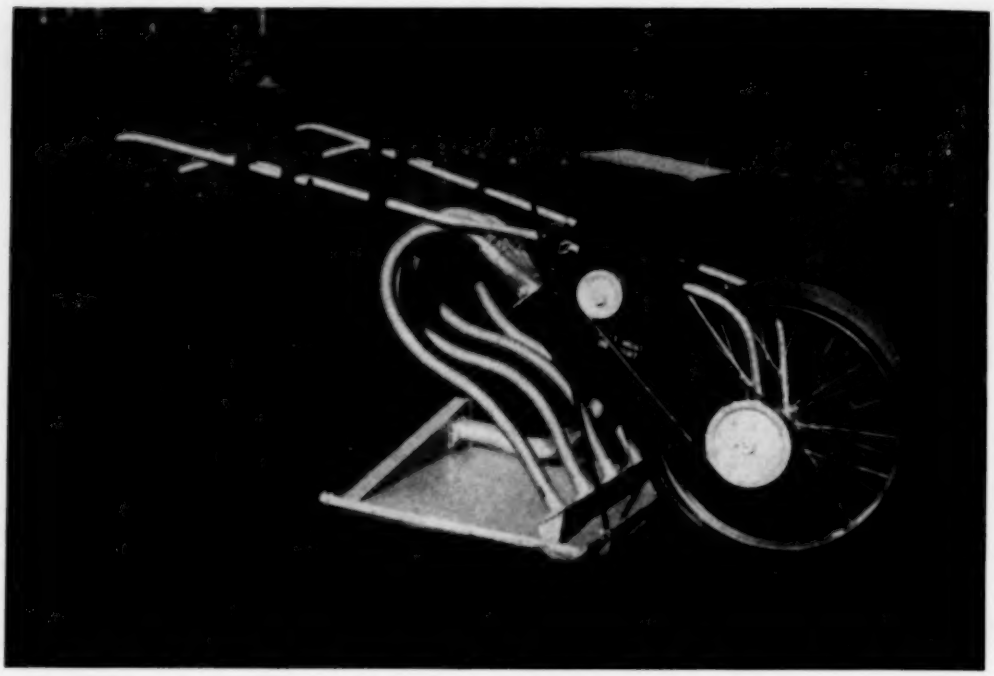

FIG. 1.—The newly designed turf dusting machine.

(Farmingdale) a heavily infested area on the Beth Page Polo Field was selected for preliminary chinch-bug control experiments with the older type duster.[1] This was marked off into six linear plots, each 10 feet by 40 feet. The turf in this area, composed of colonial bent grass, was quite dense and formed a mat over the soil. Thus furnished an ideal testing ground to show the effectiveness of the duster. In these experiments the duster was powered with a small gasoline motor. A preliminary survey in the selected area showed approximately 150 bugs, of all stages, per square foot. In making the application the duster went over each plot at least four times. At the time of the application the temperature was 75 degrees F., the sky was cloudy, and there was a light breeze.

Table 1 shows the results obtained with five different dust combinations applied August 16, 1939, Mortality counts were made at random in each plot two days later. Chinch bugs unable to crawl away at this time were considered dead.

[1] This machine works on the same principle as the one described. The differences are that the newer machine is less bulky, more adjustable, and gives a more penetrating and even distribution of the dust.

**Table 1.—Results of preliminary experiments for the control of chinch bugs.**

| MATERIALS | RATE PER 1,000 SQ. FT. | TOTAL INSECTS COUNTED | MORTALITY (PERCENTAGE) |
|---|---|---|---|
| 10% *Cyanogas*[1] Talc | 10 lbs. | 76 | 26.3 |
| 1% Tobacco dust 5% *Cyanogas*[1] | 12 lbs. | 100 | 31.0 |
| 1% Rotenone[2] 10% *Cyanogas*[1] Talc | 8 lbs. | 101 | 92.1 |
| 0.75% Rotenone 5% *Stanter Dispersing Oil* Talc | 12 lbs. | 112 | 93.7 |
| 1% Rotenone Talc | 12 lbs. | 87 | 97.7 |
| Check | 0 | 100 | 0 |

[1] Supplied through the kindness of Dr. Horsfall of the American Cyanamid and Chemical Co.

[2] The rotenone bearing dusts in the experiments were made from ground derris (4% rotenone) with talc as the diluent.

The results indicate that rotenone is highly toxic to all stages of the chinch bug, and that, at the most, half the

amount of dust recommended by MacLeod and Maxwell (1937) is effective. The dust containing the 10 per cent *Cyanogas G-fumigant* (42 per cent calcium cyanide) killed only a small percentage of the chinch bugs, although all appeared dead for a few hours after the application. The *Cyanogas* was also of doubtful value when added to other dusts. Tobacco dust is apparently not effective in light concentrations. The addition of small amounts of oils (one or two per cent) to rotenone dusts holds some promise of increasing their effectiveness and decreasing loss through drift. The five per cent oil used in the experiment made too heavy a dust. The use of heavy dusts, such as *Pyrophyllite* and *Loomis talc*, as carriers appears to increase the penetration of dusts into turf.

On September 20 a large and very dense Colonial Bent lawn was found to be swarming with chinch bugs, mostly in the adult stage. Large areas of turf had been killed and injury was increasing daily. Three days later the entire lawn was treated with a one per cent rotenone-talc dust at the rate of 10 pounds per 1,000 square feet. In making the application the turf duster, this time traction driven, went over the lawn twice, the second time at right angles to the first direction. The day was clear with a temperature of 80 degrees Mortality counts were made five days after the applications. At this time the grass was beginning to become green again in many places. Mortality counts were taken in three different places, and out of a total of 302 chinch bugs counted only nine were still living away. Since it is much easier to find living chinch bugs than to find dead ones the control obtained in the tests is probably better than that indicated. Also, rotenone has a delayed toxic action, therefore a greater mortality might be expected after about a week. No injury to the turf was observed from any of the applications. Further tests to determine the most economical and effective dust formula are planned for this summer.

DISCUSSION AND CONCLUSIONS.—A machine was designed which uses new principles in the application of dusts to turfs. This machine drives dusts evenly into the turf and draws back into the air stream by means of a vacuum return some of the waste dust. By using these new principles of application economic control of hairy chinch bugs may be obtained with one-third the amount of 1 per cent rotenone dust formerly recommended. Light even applications of lead arsenate dust to turf for white grub and sod-webworm control are also made practical through the use of this newly designed machine.—1-11-40.

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# Determination of Mineral Oil Deposits on Plant Surfaces in Field and Laboratory

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During the last two years the laboratory method of Tihenko and Hensill (1937) has been adapted to the determination of mineral oil deposits on orange leaves of both the Valencia and Navel varieties and on lemon leaves sprayed and sampled in the field. The resulting changes in technique and other factors concerned with the field and laboratory work are described and discussed in this paper.

TECHNIQUE.—Samples of 100 leaves to each tank of spray are picked from four trees (25 leaves from each tree) freshly sprayed with material from the middle portion of each tank. Samples are not taken, however, until the tank is completely sprayed out, which allows about

* Contribution from research laboratories of California Spray-Chemical Corporation. Early publication of this paper has been secured by payment of the printing charges.

10 minutes for the leaves to drain.

Leaves are collected in a two-liter beaker, being snipped off with a pair of scissors and falling into the beaker, it being unnecessary to touch them with the hands. The leaves are then washed in acetone contained in two 2-liter beakers each containing 300 to 350 cc. of solvent. Leaves are washed, 25 at a time, for 1 minute in the first beaker and one-half minute in the second beaker or rinse.

To facilitate handling leaves while they are being washed, a spoon cut from one-fourth inch mesh wire screen is used in each beaker. These wire spoons are so constructed that the basal portion is flat, just fitting the bottom of the beaker, and of the right size to slide in and out of the beaker with ease. The handle of each spoon is at right angles to the base and extends to the top of the beaker. With these spoons many leaves can be lifted at one time and drained free of acetone as they are removed from the beaker. Leaves are transferred from the collecting beaker to the washing beaker by means of cover-glass forceps, the shape of which enables the operator to pick up leaves with ease. Glass stirring rods are used to move the leaves about in the acetone solution in order to insure thorough washing. After washing, leaves are measured for surface area determinations (Tihenko and Hensill 1937).

As the washing of each 100 leaf sample is completed, the acetone from both beakers is transferred to a one-liter Erlenmeyer flask. The beakers and the collecting beaker are rinsed with acetone, the solutions all being put into the same one-liter flask. Before rinsing, all liquid in the bottom of the collecting beaker should be discarded.

The liter flasks, after being corked, are taken to the laboratory and placed in a water bath at 70 degrees C. where the acetone is distilled off and partly recovered from a condenser. The residue in the bottom of the flask is transferred to a 250 cc. Erlenmeyer flask. The liter flask is rinsed three or four times with about 25 cc. of petroleum ether (boiling point 30–60 degrees C.). The petroleum ether is distilled from the small Erlenmeyer flasks through a condenser and recovered.

From the 250 cc. Erlenmeyer flasks, the residue is transferred to sulfonation bottles with petroleum ether. Approximately 30 cc. of petroleum ether is used in transferring each sample and rinsing the flask several times. Transfers are made through a two inch glass funnel, the stem of which has been drawn out to a size fitting into the neck of the sulfonation bottle and containing a small plug of glass wool which serves as a filter. The petroleum ether is evaporated from the sulfonation bottle on a hot-plate or water bath. This evaporation must be done slowly and carefully to prevent boiling over of the ether. The samples are now ready for sulfonation. The sulfonation bottles used in this work are of two sizes, but are of approximately 50 cc. capacity. One bottle is 16.5 centimeters in height, the neck of the bottle being 10 centimeters long with a 7 centimeter graduated portion. The inside diameter of the neck is 0.6 centimeter. The graduated portion holds 2 cc. and is graduated into 50 divisions, each division representing 0.04 cc. The second bottle is also 16.5 centimeters in height, the neck of the bottle being 9.5 centimeters in length with a 6.7 centimeter graduated portion. The inside diameter of the neck is 0.5 centimeter. The capacity of the graduated portion is 1.6 cc. It is divided into 80 divisions, each of which represents 0.02 cc.

Sulfuric acid, C.P., 95.5 to 96.5 per cent, is used for sulfonation, 20 cc. being added to each bottle. As the samples always contain some water, the acid must be added very slowly to avoid spattering. The water contained in these samples does not affect the sulfonation for two reasons. First, in calibrating the sulfonation bottles and making up the oil determination curves mentioned below, 5 cc. of water is added to each sulfonation bottle along with a very small amount of fine dirt and some acetone washings of unsprayed citrus leaves. Thus curves for oil determination are made up very closely approximating the conditions under which actual tests are made. Second, the proportion of sulfuric acid to oil is so much greater in these tests than in ordinary sulfonation tests that the effects of water on the sulfonation are minimized. Samples are sulfonated for 1 hour at 100 degrees C. with 10 seconds' shaking every 10 minutes. After sulfonation the bottles are filled into the neck with more sulfuric acid and centrifuged for 20 minutes in two 10 minute periods, readings being taken

after each period. It has been found that best results are obtained when the bottle is filled after sulfonation with acid heated to 60–65 degrees C. and when the bowl of the centrifuge is held at 60–65 degrees C. during the period of centrifuging. A few drops of diethyl sulfate added to the bottle just before centrifuging will aid in making the oil layer definite.

Sulfonation bottles must be calibrated by making tests with known amounts of oil which are weighed into each bottle. Plotting milligrams of oil introduced against divisions or cubic centimeters recovered will provide a curve from which the amounts of oil in other readings may be determined. A curve should be made for each oil having different unsulfonatable residue and for light and heavy oils. It has not been possible to determine any difference in this respect between light-medium and medium oils.

Tests of the same nature as the field tests have been run with this technique in the laboratory and were sprayed in the manner described in the previous article (Tihenko and Hensill, 1937).

REPRODUCIBILITY OF RESULTS IN FIELD TESTS.—It has always been possible, except for an occasional mishap of some kind to duplicate results on two different tanks of the same material. This has held true for any given grove and with rotating and non-rotating spray crews. Deposits in different groves naturally vary, due to differences in the trees, the spraying equipment and the spray crews as well as various other factors. In table 1 some of the results of various duplicate tests are presented.

The results in table 1 are based on samples of 100 leaves for each test, the surface area for each batch of leaves being approximately 1,000 square inches. For the most part, samples were taken as described previously; in some cases, however, it was necessary to sample after a certain time interval due to irregularity in spray, weather and other factors.

The term "emulsive oil" as used in table 1, and in other tables refers to an oil containing a small percentage of oil-soluble material which causes the oil to emulsify when it is agitated with water. The emulsive oils generally carry a guarantee of 96 to 98 per cent petroleum oil. "Flowable emulsion" refers to an emulsion which has not been pumped to the stiffness of the ordinary emulsion. This type of emulsion can be drawn from drums with spigots. The emulsions referred to in all tables carry a guarantee of 83 per cent petroleum oil. Characteristics of the oils used in the tests included in the tables, based on the California State Department of Agriculture classification are as follows: light-medium; viscosity 66 seconds, 55 per cent distillation at 636 degrees F., unsulfonated residue 92 per cent; medium; viscosity 75 seconds, 42 per cent distillation at 636 degrees F., unsulfonated residue 92 per cent; heavy; viscosity 92 seconds, 26 per cent distillation at 636 degrees F., unsulfonated residue 94 per cent; dormant oil; viscosity 104 seconds, 26 per cent distillation at 636 degrees F., unsulfonated residue 70 per cent.

REPRODUCIBILITY OF RESULTS IN LABORATORY TESTS.—Oil deposit tests were also run at the laboratory using the apparatus described by Tihenko and Hensill, 1937. The technique of these tests was the same as in field tests. Leaves were taken from trees in a grove adjoining the laboratory. Forty leaves were placed on the turn table by pinning them together at their tips. The leaf samples were smaller in the laboratory tests, but samples could be picked more uniformly and spraying could be done under well regulated and controlled conditions. It is easier, as a rule, to obtain concordant results in laboratory tests.

In table 2 some results of duplicate tests made with three different sprays are presented. The tests were made at an interval of 17 days, Valencia orange leaves being used.

OIL DEPOSIT TESTS ON BARK.—The tests on bark have given good duplication of results, but only a few tests have been run as compared to the number on leaves.

Material used for the bark tests was the young growth on Kelsey plums; better described as "the year's sucker growth." In the orchard where this material was obtained, suckers grow annually on the trees to a length of 4 to 6 feet and sometimes approach an inch in diameter by the time they stop growing in the fall. The bark on these suckers, except for the basal portion in some cases, is fairly smooth and hard and has made a good natural surface for deposit tests. Some tests were also made using apple bark from a similar source.

**Table 1.—Reproducibility of determinations of oil deposited on leaves in the field.***

| Spray | Date Applied | Kind of Leaves | Oil Per Square Inch Leaf Surface |
|---|---|---|---|
| 1. Flowable Emulsion, Medium 2% | 10/ 1/37 | Lemon | .56 mg. |
| 1a. Duplicate of 1 | 10/ 1/37 | Lemon | .51 mg. |
| 2. Emulsive Oil, Medium 2% | 10/ 1/37 | Lemon | .60 mg. |
| 2a. Duplicate of 2 | 10/ 1/37 | Lemon | .64 mg. |
| 3. Emulsive Oil, Light-Medium, Formula 1, 1¾% | 7/21/38 | Valencia Orange | .42 mg. |
| 3a. Duplicate of 3 | 7/21/38 | Valencia Orange | .41 mg. |
| 4. Emulsive Oil, Light-Medium, Formula 2, 1¾% | 7/21/38 | Valencia Orange | .46 mg. |
| 4a. Duplicate of 4 | 7/21/38 | Valencia Orange | .44 mg. |
| 5. Emulsive Oil, Medium, Formula 1, 2% | 7/29/38 | Lemon | .48 mg. |
| 5a. Duplicate of 5 | 7/29/38 | Lemon | .48 mg. |
| 6. Emulsive Oil, Medium, Formula 2, 2% | 7/29/38 | Lemon | .40 mg. |
| 6a. Duplicate of 6 | 7/29/38 | Lemon | .38 mg. |
| 7. Emulsive Oil, Medium, Formula 3, 2% | 7/29/38 | Lemon | .48 mg. |
| 7a. Duplicate of 7 | 7/29/38 | Lemon | .47 mg. |
| 8. Emulsive Oil, Medium, Formula 1, 2% | 9/ 3/38 | Lemon | .73 mg. |
| 8a. Duplicate of 8 | 9/ 3/38 | Lemon | .72 mg. |
| 9. Emulsive Oil, Medium, Formula 2, 2% | 9/ 3/38 | Lemon | .61 mg. |
| 9a. Duplicate of 9 | 9/ 3/38 | Lemon | .59 mg. |
| 10. Emulsive Oil, Light-Medium, Formula 1, 1¾% | 1/25/39 | Valencia Orange | .51 mg. |
| 10a. Duplicate of 10 | 2/15/39 | Valencia Orange | .53 mg. |
| 11. Emulsive Oil, Light-Medium, Formula 2, 1¾% | 1/25/39 | Valencia Orange | .44 mg. |
| 11a. Duplicate of 11 | 2/15/39 | Valencia Orange | .46 mg. |
| 12. Emulsive Oil, Light-Medium, 1¾% | 4/10/39 | Valencia Orange | .41 mg. |
| 12a. Duplicate of 12 | 4/10/39 | Valencia Orange | .43 mg. |

* All duplicate tests were made on separate tanks of spray.

Twig sections averaging about one-half inch in diameter and 4 to 5 inches in length were cut from the suckers with large pruning shears. The twig sections were suspended on the turntable, sprayed, and the oil removed with acetone in the same manner as is done with leaves. Some oil deposit tests on twigs were also run on

twigs cut after spraying in the field. The middle diameter of each twig and its length were used for computing its surface area.

**Table 2.—Reproducibility of determinations of oil deposited on leaves in the laboratory. Tests applied April 27 and May 14, 1938.**

| Spray | Oil Per Square Inch of Leaf Surface |
|---|---|
| 1. Flowable Emulsion, Light-Medium, 2% | .64 mg. |
| 1a. Duplicate of 1 | .63 mg. |
| 2. Emulsive Oil, Light-Medium, Formula 1, 1¾% | .68 mg. |
| 2a. Duplicate of 2 | .70 mg. |
| 3. Emulsive Oil, Light-Medium, Formula 2, 1¾% | .49 mg. |
| 3a. Duplicate of 3 | .50 mg. |

Table 3 shows the results obtained in field and laboratory oil deposit tests on plum twigs.

SUMMARY.—A method for determining the deposit of mineral oil on foliage at the time of application has been developed and used extensively. The results are not affected by penetration of oil and other factors. This method has given concordant results in duplicate tests not only on citrus leaves both in the field and laboratory, but also on the twigs (bark surface) of deciduous trees in field and laboratory.

**Table 3.—Reproducibility of determinations of oil deposited on twigs in field (1 and 1a) and laboratory (2 and 2a).***

| Spray | Date of Test | Oil Per Square Inch of Bark Surface |
|---|---|---|
| 1. Emulsive Oil, Heavy, 3% | 1/26/38 | 1.04 mg. |
| 1a. Duplicate of 1 | 1/26/38 | .99 mg. |
| 2. Flowable Emulsion, Dormant Oil, 3% | 10/19/38 | 1.70 mg. |
| 2a. Duplicate of 2 | 10/19/38 | 1.78 mg. |

* In tests 1 and 1a, 50 twig sections were used in each test giving an average of about 320 square inches of surface per sample. In tests 2 and 2a, 30 twig sections per sample were used giving a correspondingly smaller surface area.

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# Preparation of Commercial Calcium Arsenate for Use as an Orchard Insecticide[1]

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In the past the manufacture of calcium arsenate has been confined mainly to the preparation of a product suitable for use in controlling the boll weevil. Recent investigations inspired by the quest for lead arsenate substitutes have shown that calcium arsenate has a definite place in the spray programs in certain of our fruit growing areas. Its use in commercial apple orchards in the Hudson River Valley of New York State is an established practice and has been partially responsible for the fact that practically all apples grown in this area meet the present state and federal residue requirements without supplementary fruit cleaning operations. Experience has shown that successful use of calcium arsenate in orchard treatment depends primarily on two factors: effectiveness in controlling insects and toxicity to foliage. The latter is commonly referred to as "safeness to foliage."

Pearce *et al.* (1935) described a method for determining water-soluble arsenic in commercial calcium arsenate which may be used as an index of the safeness to foliage of such products. These workers considered that a calcium arsenate having a water-soluble arsenic content of not more than 0.75 per cent $As_2O_5$, as determined by their method, would be relatively "safe"[2] to most foliage. Waters and Witman (1937) have studied factors involved in the manufacture of calcium

[1] Approved by the Director of the New York State Agricultural Experiment Station for publication as Journal Paper No. 330, April 18, 1939.

[2] The terms "safe" and "unsafe" as used throughout this paper are defined on pages 3 and 4 of reference (Pearce *et al.* 1935).

arsenate which meets this specification. It appears that no great difficulty is experienced by manufacturers in producing the "safe type" of product, as evidenced by the number of such preparations now on the market. Some consideration has been given (Chapman *et al.*, 1934; Pearce *et al.*, 1935) to the comparative effectiveness of "safe" and "unsafe" calcium arsenates in controlling insects, but as yet no index for judging this characteristic of commercial preparations has been made available to the manufacturer. This paper describes a method used to prepare experimental batches of calcium arsenate of the "safe" type, which can be easily modified for commercial production, and field tests of the material thus obtained in comparison with a commercial product as well as with the standard lead arsenate treatment.

THE PREPARATION OF EXPERIMENTAL QUANTITIES OF "SAFE" CALCIUM ARSENATE.—The common commercial procedure for making calcium arsenate consists in adding a concentrated solution of arsenic acid to a slurry of freshly slaked lime, the latter being agitated continuously by means of mechanical stirrers. As Waters and Witman (1937) have pointed out, unless attention is directed towards control of temperature, concentration of reagents, and rate of stirring, products of variable "safeness" will result.

Work on the chemistry and field behavior of calcium arsenates at this station indicated that a "safe" product could be prepared without much difficulty; and after some small laboratory batches with consistent properties had been obtained, the following standard procedure for making sufficient quantities for field tests was adopted.

Six pounds of a high grade commercial hydrated lime ($Ca(OH)_2$) were suspended in 20 to 25 gallons of water contained in a 55 gallon metal oil drum. A source of steam was led into the suspension by means of a pipe having several openings on the submerged end for steam outlets. A valve on the pipe served as a means of controlling the steam. Steam was introduced into the suspension until this was brought to a vigorous boil and then a solution containing $4\frac{3}{4}$ pounds of Baker's technical grade $As_2O_5$ dissolved in about 4 gallons of water was added at a moderate rate while the suspension was kept continuously boiling by means of the steam. About 10 to 15 minutes were required to add all of the arsenic acid. No special precautions were taken for this operation. Laboratory experiments indicated that under such conditions of high temperature, diluted reagents and vigorous agitation during addition of the arsenic acid, no further treatment of the product would be necessary in order to obtain a product well under the limit of 0.75 per cent water-soluble arsenic ($As_2O_5$). However, all batches prepared were subjected to the treatment of continuing the vigorous boiling with steam for at least $1\frac{1}{2}$ hours after all the arsenic acid had been added. The product was then allowed to cool and the precipitate to settle. The supernatant liquor was siphoned off and the remaining fairly dense suspension was thoroughly mixed and sampled for analysis. The product was then stored in 5 gallon tins ready for use. Each batch was analyzed for water content in order that spray tank dilutions could be determined accurately. Total arsenic and water-soluble arsenic were also determined, the method of Pearce *et al.* (1935) being used for the latter.

The foregoing procedure was used to prepare about 200 pounds of a "safe" calcium arsenate in 10 pound batches which were tested in the field to determine safeness to foliage and toxicity to a number of insects, principally codling moth. The total arsenic content of the different batches was quite constant showing a variation from 45.7 to 45.9 per cent expressed as $As_2O_5$ on dry weight basis. Also the water-soluble arsenic content by the method cited was constant within a narrow range: 0.45 to 0.55 per cent expressed as $As_2O_5$ on dry weight basis.

FIELD TESTS.—The calcium arsenate prepared by the described procedure was compared with a "safe" type of commercial calcium arsenate and a commercial lead arsenate with respect to its safeness to foliage and effectiveness in controlling codling moth. Both the commercial arsenicals employed were in the form of dry powders as commonly available on the open market. Table 1 summarizes the field data. A similar set of data was obtained in two other spray plats but are not included because the behavior of the materials under test was practically identical.

CODLING MOTH CONTROL.—The data in table 1 show quite distinctly that calcium arsenate "A" (Plats 1, 2, 3) compares very well with the standard lead arsenate treatment (Plat 7), all showing a control efficiency of better than 95 per cent; whereas calcium arsenate "B" is definitely inferior to the former materials, the control efficiency ranging from 53.5 to 73.1 per cent. Some differences in spray load were observed from analyses of the fruit at harvest. However, such differences were not considered great enough to account for such large differences in control. Furthermore, the residue loads in the unreported experimental plats did not show any appreciable differences but the control differences were essentially the same as those shown in table 1. It is possible that the differences in control between the two calcium arsenates may be partially accounted for by differences in the physical condition of the products, such as particle size and original form (*i.e.*, paste and dry powdered). The recent work of Siegler and Goodhue (1939) would indicate that, within limits, particle size of calcium arsenates is not a major factor in insect toxicity except as it reflects to some extent the chemical composition of commercial preparations. It seems extremely unlikely that the large control differences observed can be explained on the basis that one of the materials was in paste form and the other was a dry powdered form, although such a possible explanation would undoubtedly have to be considered if the differences in control were relatively small.

A more satisfactory explanation of the behavior of the materials is afforded by consideration of the difference in chemical constitution of the materials as indicated by their water-soluble arsenic content determined by the method of Pearce *et al.* (1935). (Nelson and Cassil (1937) have recently discussed the composition of commercial calcium arsenates.) Calcium arsenate "A" contained 0.45 to 0.55 per cent water-soluble arsenic (expressed as $As_2O_5$), whereas calcium arsenate "B" contained 0.25 per cent. It has been recognized by investigators of calcium arsenate that it is possible to prepare extremely stable calcium arsenates which are quite safe to foliage and show a correspondingly low toxicity to insects by the use of rather severe heat treatments such as calcining of the product. Calcium arsenate "B" is a product prepared on a commercial scale under more severe temperature conditions than that of calcium arsenate "A." It has been the experience of the writers that there is a definite correlation between stability of calcium arsenates and their water-soluble arsenic content as determined by the method cited. That is, products of high stability show a low water-soluble arsenic content. It seems reasonable to conclude that the differences in control efficiency of the two materials may be accounted for primarily by their differences in chemical constitution.

**Table 1.—Comparison of calcium arsenate and lead arsenate 1936 season.**

| Plat | Spray Schedule | Worm Holes per 100 Apples | Per Cent Efficiency Based on Worm Infested Fruit | Foliage Injury Ratings |
|---|---|---|---|---|
| 1 | Calcium Arsenate A | 6.6 | 95.3 | 2 |
| 2 | Calcium Arsenate A+3 lbs. Hydrated Lime | 3.6 | 97.5 | 6 |
| 3 | Calcium Arsenate A+9 lbs. Hydrated Lime | 3.1 | 97.8 | 9 |
| 4 | Calcium Arsenate B | 38.2 | 73.1 | 6 |
| 5 | Calcium Arsenate B+3 lbs. Hydrated Lime | 66.0 | 53.5 | 9 |
| 6 | Calcium Arsenate B+9 lbs. Hydrated Lime | 46.5 | 67.2 | 9 |
| 7 | Lead Arsenate+2 lbs. Lime+1 lb. Soy-Bean Flour | 4.9 | 96.5 | 9 |
| 8 | Check—No Spray | 141.8 | — | 10 |

All arsenicals were used at the rate of 3 lbs. to 100 gals. of water. Amounts of other materials are given in lbs. per 100 gals. of water. All calcium arsenate sprays contained ½ lb. milk powder as spreader. Five applications were made throughout the growing season at about 2 week intervals. Variety—R. I. Greening.
Calcium Arsenate A—"Safe" type prepared by authors (0.45% water-soluble $As_2O_5$).
Calcium Arsenate B—A commercial product prepared and sold as a "safe" type (0.25% water-soluble $As_2O_5$).

INJURY.—The behavior of the materials with respect to their toxicity to the foliage lends further support to the belief that they were fundamentally different in chemical constitution. In column 5 of table 1 the relative injury ratings of the different treatments are given. The ratings are given in an arbitrary scale of 0–10, zero representing complete defoliation and ten representing normal foliage on the unsprayed trees of the same plat. The manner of estimating the ratings was the same as that described by Chapman *et al.* (1934), except that ratings were taken at the end of the season.

The injury data shows that calcium arsenate "A" was definitely inferior to calcium arsenate "B" in safeness to foliage.

The use of lime in the sprays showed a decided improvement in safeness. Although lime is commonly recommended as an injury corrective at the rate of 3 pounds per pound of calcium arsenate, it does not always behave so effectively in this capacity as these results would indicate.

The significance of the injury data is apparent when one considers that it parallels the control data; that is, calcium arsenate "A" showed a higher toxicity towards both plant and insect while "B" showed a relatively lower toxicity to both. The writers believe that the differences in toxicity is most satisfactorily explained by chemical differences which may be partially indicated by water-soluble arsenic content.

DISCUSSION.—The data presented were collected during the 1936 season. It is of interest to note that spray injury of various types was unusually prevalent in fruit growing areas of New York during this year, particularly arsenical injury. For this reason, the "safe" types of commercial calcium arsenate produced more injury than was experienced in previous years. This fact indicates that, although a better understanding of the chemistry and field behavior of calcium arsenates has been attained in recent years and has resulted in improved commercial preparations, a commercial calcium arsenate has not been produced which does not show considerable variability in safeness to foliage with seasonal variations. Further, the present results signify that the "safe" types of calcium arsenate are liable to large variation in effectiveness in controlling insects as well.*—6-7-39.

* The authors wish to express herewith their thanks to S. W. Harman of the Division of Entomology of this Station for supplying the field data presented in this paper.

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# The Activity of Adult Codling Moths as Indicated by Captures of Marked Moths

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An investigation of bait traps for the control of the codling moth has been carried on at Yakima, Wash., for several years. As a part of these studies the efficiency of certain baits was tested by releasing marked moths in orchards in which bait traps had been hung. At the same time observations were made to obtain information on moth behavior. The studies reported herein were begun in 1931, but since the work of the first year[1] was only preliminary those results are not included.

EXPERIMENTAL PROCEDURE.—In a general way the method used in this work was an adaptation of one used by Yetter and Steiner (1932) in work with the oriental fruit moth. Codling moth larvae were collected from banded trees and stored in a cool cellar until a supply of moths was needed. Moths were reared from these larvae in an open type outdoor insectary. Collections of moths from the emergence jars were made from 2 to 3 hours after emergence and the moths put in a cool place to prevent injury that might be caused by undue activity in a limited space. The moths that had emerged during a 24-hour period were placed in a small screened cage and sprayed with one of several alcohol-soluble dyes. The dye

[1] Conducted by A. R. Rolfs.

used for all moths released in the baited areas was eosin Y at the dilution of 2 grams to 100 cubic centimeters of ethyl alcohol. Other dyes used for marking moths released at various distances outside the baited areas were methyl green, toluidin blue, orange G, acetin blue, and congo red. The most satisfactory of the various dyes used was eosin Y.

The solutions were applied to the moths with a small hand sprayer, the spray being directed from within as well as from without the cage. This assured the application of a good mist of spray to all sides of the insect. Various methods of marking the moths were tried, but it was necessary to give them a generous application on the ventral and dorsal sides to make them readily distinguishable in the bait, when in traps of the type used in these experiments. Even then it was difficult at times to identify the marked moths. As the moths were sprayed they fell to the bottom of the cage, where they were dried quickly by the air currents from an electric fan. As soon as the moths were dry they returned to the sides of the cage and no harmful effects of the spraying were noted.

The spray applications were made generally between 8 and 10 A.M., and the moths were taken to the orchard immediately and released. Examination of the containers within 2 hours after liberation showed that less than 1 per cent of the moths remained. After leaving the containers the moths would usually fly to near-by trees. It is assumed that their subsequent activity was normal, although it is not known whether the dye interfered with their responses to external stimuli.

The bait traps were filled with 1 quart of the liquid bait several days before the release of moths. At each observation water was added to the baits to take the place of that lost through evaporation.

Releases were made on successive days whenever enough moths were available. Under these conditions it was not possible to obtain information on the interval between release and capture because there was no way of determining from which lot the moths came. Several individual releases were made, however, in order to determine the period of time between release and capture. The first five and last eight releases were made in trees with baits. The other releases were made in unbaited trees each within 28 feet of a baited tree.

Several different bait mixtures were used. These mixtures resulted from many tests made with chemicals to increase the efficiency of the bait. The baits used in each release are described as follows:

*Bait A.* One part by volume of molasses, 10 parts by volume of water, and 1 cake of yeast to 10 gallons of bait. This bait was used as a standard in comparing the efficiency of other baits.

*Bait B.* Standard bait (A) and .5 cubic centimeter of citral per quart of bait.

*Bait C.* Standard bait (A) and .5 cubic centimeter of pine tar oil per quart of bait.

*Bait D.* Standard bait (A) and a dispenser of pine tar oil.

*Bait E.* Standard bait (A), 1 cubic centimeter of nicotine sulfate (40 per cent nicotine) per quart of bait, and a dispenser of pine tar oil.

The dispenser for vaporizing the pine tar oil consisted of a 1-ounce glass bottle with a mouth 18 millimeters in diameter. To the neck of the bottle was attached a small galvanized iron disk to prevent rain from entering. The bottle filled with the oil was placed in the center of the bait pot, with the mouth about 1 inch above the surface of the bait, and held there by means of a bent wire fastened to the sides of the bait pot.

For the recovery of the moths bait pots containing about 1 quart of the bait were placed in the upper center branches of the trees. These baits were hung from poles and lowered and raised by means of a cord and pulley. Particular care was taken to have all baits in the open and about 18 inches below the top level of the trees. The baits in most cases were about 16 feet from the ground. This position appeared to be the most favorable for moth recovery.

Releases 1 to 13 (table 1) were made in the Gilbert orchard. The point of release was approximately in the middle of an 80-acre apple orchard about $\frac{1}{4}$ mile wide by $\frac{1}{2}$ mile long. In the first four releases 45 baits were equally distributed over an area of about 8 acres. In releases 5 to 10, 92 baits were distributed throughout this

same area. Releases 11, 12, and 13 were made in a 5-acre baited area containing 253 trees with one bait to each tree.

Releases 14, 15, and 16 were made in a 5-acre block of the Siepman orchard. A total of 276 trees were baited. This orchard was somewhat isolated, having apple trees adjacent only on the west side. The outside edges of the baited area did not reach the outside rows of the orchard; therefore all sides of the baited area were adjacent to at least several rows of unbaited trees.

Release 17 was made in the Bjorge orchard, consisting of 20 acres, in half of which there was one bait to a tree. This orchard was surrounded by other orchards except on the west side. Of the 446 trees in the area approximately 160 in the central part were baited with five different bait solutions. The remainder of the orchard was baited with a mixture of 100 cubic centimeters of molasses, 1 cubic centimeter of nicotine sulfate (40 per cent nicotine), and 900 cubic centimeters of water and a dispenser of pine tar oil. This release consisted of several lots of moths liberated at frequent intervals during the season of 1938.

The traps were examined for recovery of marked moths at least every third day and at shorter intervals whenever convenient. In some cases observations were possible every day. The sex of the moths was not determined before they were liberated and only a few sex determinations were made after the moths had been recovered.

**Table 1.—Summary of records on release and recovery of marked codling moths, Yakima, Wash.**

| Release No. | Date of Release* | Bait | Number of Moths Released | Percentage Moths Recovered | Distance Traveled, Feet: Maximum | Distance Traveled, Feet: Average |
|---|---|---|---|---|---|---|
| | 1932 | | | | | |
| 1 | July 30 | B | 395 | 35.8 | 305 | 168 |
| 2 | Aug. 18 | B | 290 | 40.7 | 305 | 126 |
| | 1933 | | | | | |
| 3 | July 10 | A | 230 | 34.8 | 302 | 157 |
| 4 | Aug. 1 | A | 195 | 15.9 | 302 | 182 |
| 5 | Aug. 12, 13, 17, 22 | A | 729 | 27.3 | 363 | 180 |
| | 1934 | | | | | |
| 6 | June 6 | A | 157 | 56.1 | 363 | 112 |
| 7 | June 14, 15 | A | 161 | 24.2 | 277 | 125 |
| 8 | July 9, 11 | C | 186 | 71.5 | 363 | 108 |
| 9 | July 25 | A | 161 | 36.8 | 313 | 125 |
| 10 | Aug. 30, 31 | D | 191 | 51.8 | 363 | 179 |
| | 1936 | | | | | |
| 11 | June 6 | D | 100 | 6.0 | 336 | 126 |
| 12 | June 15 | D | 130 | 15.4 | 230 | 157 |
| 13 | July 9 | D | 143 | 72.7 | 336 | 112 |
| 14 | June 8, 9 | D | 160 | 36.8 | 312 | 142 |
| 15 | July 6, 7 | D | 185 | 96.2 | 336 | 132 |
| 16 | July 25 | D | 193 | 86.5 | 336 | 167 |
| | 1938 | | | | | |
| 17 | May 24, July 14, 16, 18, 20, 25, 27, 29, Aug. 1, 3 | E | 1,267 | 43.9 | 355 | 132 |

* No moths were released in 1935 and 1937.

MOTHS RECOVERED.—Table 1 shows that the highest percentage recovery of marked moths occurred following releases 15 and 16. It is the writer's opinion that this was due to the fact that the orchard was somewhat isolated and that there were few unbaited trees to attract the moths. In previous experiments it was found that the addition of pine tar oil to the standard bait improved the mixture considerably, and better results were obtained when the oil was used in a separate container than when it was emulsified in the bait solution. The addition of citral to the standard bait increased its effectiveness, although in the experiments recorded herein the improvement is very slight. The results suggest that a larger proportion of moths are caught when there is a bait to each tree than when fewer baits are used. In considering the data shown in table 1 the reader should bear in mind that the percentages of moths recovered are practically the minimum, since it was not always possible to distinguish the marked moths and all doubtful individuals were eliminated from the results.

DISTANCES TRAVELED BY MOTHS.—The distance traveled by individual moths was recorded, but as a matter of convenience in grouping the distances traveled by all moths, the following arrangement

**Table 2.—Time interval between release and recovery of marked codling moths, Yakima, Wash.**

| Number of Days After Moths Were Released | Number of Moths Recovered | Percentage of Moths Recovered (Cumulative) |
|---|---|---|
| 1 | 85 | 7.7 |
| 2 | 99 | 16.7 |
| 3 | 185 | 33.5 |
| 4 | 174 | 49.4 |
| 5 | 174 | 65.2 |
| 6 | 94 | 73.7 |
| 7 | 136 | 87.9 |
| 8 | 22 | 89.9 |
| 9 | 42 | 93.7 |
| 10 | 9 | 94.5 |
| 11 | 19 | 96.3 |
| 12 | 13 | 97.5 |
| 14 | 6 | 98.0 |
| 15 | 14 | 99.3 |
| 16 | 3 | 99.5 |
| 17 | 2 | 99.7 |
| 18 | 3 | 100.0 |

was used at the beginning of the study and continued throughout. The distances selected for each group and the percentage of moths for each are as follows: 0 to 150 feet, 58 per cent; 151 to 225 feet, 20.9 per cent; 226 to 300 feet, 14.3 per cent; 301 feet or over, 6.8 per cent. The maximum distance from the liberation point to a trap in the baited area was 363 feet. That some moths traveled farther than this was proved when a few individuals were caught in baits a quarter of a mile from the baited area. The average flight recorded in these experiments was 143 feet. The distances flown by male and female moths were approximately equal for those of which the sex was determined, which was about one-fifth.

The records obtained on the movement of moths through the orchard can reflect only part of the normal movement. Those moths taken shortly after release would undoubtedly have traveled much farther. The flight distances were limited by the size of the baited areas, and longer flights would probably have been recorded if the baited areas had been larger. The presence of the baits is of course abnormal, and greater dispersal might have occurred in their absence. The author is of the opinion that during their life period moths migrate from tree to tree within the orchard and often long distances from the point of emergence.

INTERVAL BETWEEN RELEASE AND RECOVERY.—The intervals between release and recovery for 1,100 moths are given in table 2. These experiments were carried on when first-brood moths were present in the orchards.

About 75 per cent of the moths recovered were taken within 6 days, and 90 per cent within 8 days, after release. A study of the oviposition records of caged moths of the first brood at Yakima for 1919 and 1920 shows that the moths deposited 70 per dent of their eggs within 6 and 8 days after emergence.

INFLUENCE OF WIND DIRECTION.—During 48 of the 53 days of these experiments the wind direction at 8 P.M., the time of greatest moth activity, was northwest. The minimum wind velocity was 1 mile per hour, the maximum 15, and the average 10. Of 317 moths released at five different times in the center of a square block of baited trees 37 per cent were recovered in the northwest quadrant of the baited area, 29 per cent in the northeast, 14 per cent in the southeast, and 20 per cent in the southwest. It is logical to conclude that the odors from the baits reach the moths by air movement. It may be necessary for the moths to fly against the currents of air to find the baits.

CAPTURES OF MOTHS LIBERATED OUTSIDE THE BAITED AREAS.—The results of releases made outside the baited area are given in table 3.

**Table 3.—Recoveries of moths released outside the baited areas, Yakima, Wash.**

| NUMBER OF FEET FROM POINT OF RELEASE TO NEAREST BAIT | NUMBER OF MOTHS RELEASED | PERCENTAGE OF MOTHS RECOVERED |
|---|---|---|
| 336 | 165 | 18.2 |
| 960 | 712 | 12.1 |
| 1,000 | 645 | 0.0 |
| 1,100 | 684 | 0.2 |
| 1,200 | 581 | 0.0 |
| 1,320 | 1,161 | 0.6 |
| 1,500 | 765 | 0.4 |
| 2,000 | 778 | 0.0 |
| 5,280 | 1,483 | 0.0 |
| 10,560 | 504 | 0.0 |

Two of the moths released 1,320 feet from the nearest baited trees were recovered in a bait 2,640 feet (one-half mile) from the point of release. Two of the moths released 960 feet from the nearest bait traveled 2,280 feet before entering a bait. If these moths flew in a direct line from the point of release to the bait, they crossed a 5-acre block of baited trees.

Of 712 moths released 960 feet northwest of the baited area 12.1 per cent were recovered in the 5 acres that were baited. A circle drawn with the point of release as a center and with the circumference at the outer edge of this 5 acres would include 175 acres. Thus, if the dispersion of released moths had been uniform throughout this area, only about 20 moths, or 3 per cent, would have flown to the 5-acre baited area. And yet, in this 5-acre baited area, all of which was at least 960 feet from the point of release, 12 per cent of the moths were captured, or 4 times the expected number, indicating some positive attraction to the baited area. The small proportion captured out of the total number released at outside points (table 3) indicates, however, that this attraction was not especially strong.

Although large numbers of moths are captured in the baits in apple trees, practically none are captured when the traps are placed away from the trees. This means that the attractants thus far de-

veloped are not so strong as the natural odors that attract the moths to the apple trees.

DISTRIBUTION OF CAPTURES OF UNMARKED MOTHS.—During the examination of the baits for marked moths, counts were also made of the number of unmarked moths captured. Observations in this connection have been made during the last 4 years. Without exception, the largest numbers of moths have been taken in the outside rows of the baited area. The results for 1934 are typical. Of the 43,453 moths taken in 92 traps the largest numbers were caught in the outside baits on all sides of the baited area. The 33 traps in this location averaged a total of 781 moths each, the second line of traps toward the center 375 moths, the third line 288, and the 14 traps near the center of the area 197 moths each. The results indicate that many moths came to the traps from outside the baited area. The distance from which these moths came has not been determined.

SUMMARY.—In connection with studies of the use of baits for codling moth control, which have been made during the past several years at Yakima, Wash., a number of experiments have been made with the release and recovery of marked moths. In addition to records on the proportion of the marked moths recovered, much information was obtained on their flight habits.

The percentage of recovery of marked moths ranged from 6 per cent to 96 per cent. The highest recoveries were made with baits composed of fermenting molasses with pine tar oil in an isolated orchard in which nearly every tree was baited.

Most of the moths recovered in an 8-acre baited area of an apple orchard were taken within 150 feet of the point of release. The average distance traveled was 143 feet. About three-fourths of the moths recovered were taken within 6 days. The spread of moths from the point of liberation appears to have been greatest in a northerly direction, or against the prevailing winds.

Of the moths liberated at various distances outside the baited areas very few were recovered, an indication that the bait used did not attract many of the moths long distances.—6-16-39.

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# Carcass Temperatures and Their Relation to Winter Blowfly Populations and Activity in the Southwest

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It has been found that the temperature of a carcass varies considerably from that of the surrounding air. In the Southwest blowflies breed extensively in carcasses, and their development depends upon the temperature of the breeding medium. Masses of blowfly larvae generate considerable heat, which, together with that absorbed from the sun, furnishes favorable conditions for larval development during cool weather.

Since many species of blowflies produce myiasis in livestock, and it is not generally known that high temperatures develop in carcasses, data are presented to show the possibility of flies being tided over unusually cold periods, at least in larger numbers than might be expected, and to emphasize the advantage of carcass disposal, especially the disposal of large carcasses, in winter. It will be evident that it is more pertinent to consider maximum temperatures in this connection than average temperatures.

Observations were made of 33 carcasses in southwestern Texas and 40 carcasses in southern Arizona during the winters of 1935–36 and 1936–37.

TEMPERATURES OF UNINFESTED CARCASSES.—It was observed that when blowfly activity was greatly reduced by cool weather, carcasses frequently did not

[1] The writer expresses his appreciation for the suggestions and constructive criticism made by D. C. Parman, under whose supervision this work was done.

become infested for several days following death. The temperature of carcasses varies according to climatic conditions and immediate environment. A carcass in the shade usually cools to nearer air temperatures than one exposed to the sun. The surfaces of carcasses warmed by the sun accumulate heat, a portion of which is retained overnight. The temperatures of higher temperature until larval development occurred. A small goat carcass was kept in the shade in a screened insectary during a period of moderate air temperatures. During the 19 days that the carcass remained uninfested its temperature was appreciably lower than that of the atmosphere. After blowflies were allowed to oviposit on this carcass and the larvae became established, its temperature became higher than that of the atmosphere.

**Table 1.—Temperatures of various parts of a sheep carcass, 1936.[1]**

| TIME | ATMOSPHERE | TEMPERATURE, DEGREES F. | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Atmosphere | Wool | Abdomen Near Surface | Abdomen Near Center | Mouth | Nose | Anus |
| Feb. 13: | | | | | | | | |
| 9 a.m. | Clear | 54 | 70 | | 58 | 56 | 56 | 54 |
| 1 p.m. | Clear | 84 | 98 | 101 | 84 | 84 | 75 | 74 |
| Feb. 14: | | | | | | | | |
| 9 a.m. | Clear | 59 | 71 | 60 | 60 | 62 | 62 | 58 |
| 2 p.m. | Hazy | 65 | 85 | 88 | 73 | 84 | 82 | 66 |
| Feb. 15: | | | | | | | | |
| 9 a.m. | Clear | 35 | 61 | 49 | 51 | 66 | 68 | 52 |
| 2 p.m. | Clear | 72 | 107 | 108 | 89 | 92 | 107 | 74 |
| Feb. 16: | | | | | | | | |
| 11 a.m. | Clear | 60 | 83 | 83 | 76 | 86 | 88 | 72 |
| Feb. 17: | | | | | | | | |
| 8:20 a.m. | Cloudy | 40 | 53 | 59 | 60 | — | — | 51 |
| 1:30 p.m. | Clear | 70 | 89 | 90 | 81 | — | — | — |
| Feb. 18: | | | | | | | | |
| 8:30 a.m. | Clear | 25 | 61 | 44 | 62 | — | — | — |
| 1 p.m. | Clear | 41 | 86 | 77 | 62 | — | — | — |
| Feb. 19: | | | | | | | | |
| 8 a.m. | Clear | 31 | 52 | 41 | 59 | — | — | — |
| 1 p.m. | Cloudy | 44 | 74 | 71 | 62 | — | — | — |
| Feb. 20: | | | | | | | | |
| 8 a.m. | Cloudy | 41 | 64 | 62 | 68 | — | — | — |
| 1 p.m. | Clear | 62 | 103 | 90 | 76 | — | — | — |
| Feb. 21: | | | | | | | | |
| 8 a.m. | Foggy | 39 | 66 | 82 | 85 | — | — | — |
| 1 p.m. | Clear | 68 | 97 | 109 | 88 | — | — | — |
| Feb. 22: | | | | | | | | |
| 10 a.m. | Clear | 59 | 92 | 80 | 90 | — | — | — |
| 2 p.m. | Clear | 72 | 120+ | 112 | 116 | — | — | — |
| Feb. 23: | | | | | | | | |
| 1 p.m. | Cloudy | 70 | 98 | — | 110[2] | — | — | — |
| Feb. 24: | | | | | | | | |
| 8 a.m. | Cloudy | 65 | — | — | 108[2] | — | — | — |

[1] Animal died January 28.
[2] Temperatures are of the maggot mass.

The data in table 1, showing the temperatures of the wool and of the abdominal cavity of a sheep carcass from February 13 to 16, given in table 1, show the effect of the sun on an uninfested carcass. There was no larval development except in the natural orifices until February 17. Temperatures of the body covering and within the carcass, near the surface, such as those recorded in the table, are favorable for blowfly oviposition and complete larval development.

Carcasses in the shade did not show a

Rapid decomposition of the carcasses from the action of bacteria was not in evidence when the temperatures were lower than those at which some of the species of flies are normally active. Although bacteria may have been responsible for some of the heat generated during larval development, heat from bacterial decomposition alone was not perceptible in any of the carcasses.

TEMPERATURES OF INFESTED CARCASSES.—The natural body orifices usually become infested first, but if moisture conditions are favorable flies oviposit readily on any part of the body. Often when most of the skin of the carcass is dry, conditions are favorable for oviposition in parts of the carcass that come in contact with the soil. After the eggs have hatched and the larvae have penetrated the tissues and begun development, enough heat is generated by the larvae, when added to that absorbed from the sun, to keep the carcass temperature high enough for continued larval development even when the minimum atmospheric temperature drops to 50 degrees F. or lower.

**Table 2.—Mean temperatures of six infested carcasses over periods of several days.**

| Animal | Date Temperature Records Were Begun | Number of Days of Record | Time Temperature Was Taken | Mean Temperature, Degrees F. | | | | Maximum Temperature Recorded for Maggot Mass, Degrees F. |
|---|---|---|---|---|---|---|---|---|
| | | | | Atmosphere | Wool or Mohair | Abdomen Near Surface | Abdomen Near Center | |
| Goat | Oct. 28, 1935 | 5 | 8 a.m. | 72.4 | — | — | 90.4 | 116 |
| | | | 1 p.m. | 81.8 | — | — | 99.6 | |
| | Jan. 3, 1936 | 11 | 1 p.m. | 68.3 | 115.8 | 78.2 | 69.8 | 112 |
| | Jan. 3, 1936 | 7 | 9 a.m. | 47.8 | 59.7 | 57.8 | 55.7 | 120+ |
| | | 10 | 2 p.m. | 70.7 | 95.1 | 89.0 | 57.5 | |
| Sheep | Jan. 3, 1936 | 7 | 9 a.m. | 47.8 | 52.5 | 53.9 | 53.9 | 108 |
| | | 10 | 2 p.m. | 70.7 | 91.4 | 88.8 | 62.2 | |
| | Feb. 13, 1936 | 10 | 9 a.m. | 44.3 | 67.3 | 62.2 | 66.9 | 116 |
| | | | 1 p.m. | 64.2 | 95.4 | 94.0 | 81.2 | |
| | Feb. 25, 1936 | 5 | 8 a.m. | 53.0 | 59.2 | 64.2 | 71.0 | 111 |
| | | | 1 p.m. | 72.0 | 97.4 | 88.2 | 75.4 | |

The temperatures of various parts of a sheep carcass, both before and after larval development, are shown in table 1. This sheep carcass was lying in an open, unprotected situation. The natural orifices were infested when temperature records were begun. On February 17, owing to damp weather, conditions were favorable for larval development in all parts of the body. Breaks were occurring in the skin, permitting the inner tissues to be reached by the maggots. During the following period the weather was unfavorable for larval activity, but the carcass maintained temperatures high enough to permit the larvae to continue development. The main maggot mass was active when the atmospheric temperature was 25 degrees F., but groups of maggots too small to maintain appreciable heat were inactive at this temperature. After the maggots became well established in the carcass and approached maturity a high temperature was maintained, a maximum of 116 degrees being reached.

Under environmental conditions similar to those mentioned above most carcasses showed varying temperatures during the first stages of decomposition, depending upon the weather conditions. As these studies were made during the winter months, little heat was generated by bacterial decomposition. At first the heat came from the sun, but as larval development progressed the temperature increased and remained high regardless of daily weather fluctuations. Temperatures of over 120 degrees F. have been recorded for maggot masses, but as high temperatures are harmful to the larvae they move to a more favorable environment within the carcass. Temperatures of 100 to 110 degrees were common when the air temperature was between 60 and 70 degrees. In some instances the temperature of the maggot mass was more than 50 degrees above that of the atmosphere. The average temperature of a carcass over periods of 5 to 10 days was 10 to 20

degrees higher than the atmospheric temperature, but in a number of cases the temperature of certain parts of a carcass was 70 degrees above the atmospheric temperature. The mean temperature of six infested carcasses over periods of several days at various times of the winter are given in table 2.

MINIMUM TEMPERATURES FOR ADULT ACTIVITY.—In conjunction with the observations on carcass temperatures records were kept of blowfly activity about the carcasses studied. As indicated by the amount of oviposition on carcasses having high temperatures when atmospheric temperatures were approaching a minimum for general activity of the flies, such atmospheric temperatures would not prevent active oviposition by those flies present at a carcass at such times. During cooler periods the infestation of a carcass by larvae depended upon the temperatures at which the adults became active.

The minimum temperature at which blowflies became active about carcasses studied in southwestern Texas varied somewhat according to the species. Activity of *Cynomya cadaverina* Rob.-Desv. was observed at 40 degrees F., the usual range of minimum temperature at which activity began being between 40 and 50 degrees. This species was not important in the carcasses studied. *Lucilia sericata* Meig. became active at 50 degrees, the minimum range being 50 to 55 degrees. *Sarcophaga* spp. became active at 47 degrees, the usual minimum range being 50 to 60 degrees. These flies were few in number of absent during a part of the season and observations on them were not extensive. *Calliphora* spp. were active at a minimum of 35 degrees F., the usual minimum being between 40 and 50 degrees. *Phormia regina* Meigen was active at a minimum of 41 degrees. The temperature of the wool on the sheep carcass, where this observation was made, was 86 degrees, and stimulated oviposition even though the atmospheric temperature was only 41 degrees. *P. regina* more generally became active at minimums of around 50 degrees. *Cochliomyia macellaria* F. was observed copulating and ovipositing when the atmospheric temperature was 58 degrees. The minimum for activity of this species was 51 degrees, the more general minimum being from 55 to 60 degrees. No doubt some fly activity occurs at lower temperatures, but the temperatures given are those noted at the carcasses under observation.

Other factors besides temperature, such as cloudiness, humidity, wind, time of day, and the total blowfly population of an area, influence the winter abundance and activity of blowflies about carcasses. For example, on December 18, 1935, at 1 P.M., when the atmospheric temperature was 60 degrees F., the fly population at a goat carcass was approximately 45 per cent *Cochliomyia macellaria* and 45 per cent *Phormia regina*. On December 19, at 1 P.M., when the temperature was again 60 degrees but the weather was cloudy and damp, 95 per cent of the flies at the same carcass were *P. regina*, and *C. macellaria* was not active.

Observations showed that a larger number of flies were active at midday than at the same temperature early in the morning.

The influence of these other factors on the population and activity of blowflies apparently accounts for the range of the minimum temperature at which each species becomes active.

POPULATIONS IN CARCASSES OF VARIOUS ANIMALS.—Small carcasses, such as those of jackrabbits, lambs, cats, and small dogs, were not found to develop or hold a temperature significantly above that of the atmosphere. Large carcasses, such as those of sheep, goats, cattle, and horses, which did develop high temperatures, were more favorable media for larval development. *Cochliomyia macellaria* and *Phormia regina* were the most important species developing in large carcasses. In most of the carcasses more larvae were present than could develop on the available food.

The following observations on survival of the various species were recorded in this connection. In carcasses studied during the first half of January 1936, adults of *Phormia regina* and *Cochliomyia macellaria* were present in about equal numbers. Conditions were such that in a goat carcass and a sheep carcass, caged after infestation, approximately 40 per cent of the larvae that developed were those of *C. macellaria* and 60 per cent *P. regina*. The mean atmospheric temperature from January 1 to 15, when the larvae were developing, was 54.1 degrees F. From the goat carcass only 183 *C. macellaria*

emerged. The adults of *P. regina* were not counted, but over 2 gallons by measure (approximately 60,000) emerged. Similar results were obtained from the sheep carcass. Although the larvae of *C. macellaria* had consumed a considerable portion of the food, they did not contribute materially to the blowfly population because low temperatures (minimum of 19 degrees) destroyed the pupae.

A horse carcass was under observation during the last half of January and the first half of February. *Cochliomyia macellaria* had developed in large numbers in this carcass during the preceding December. Emergence occurred at a time when the weather was unfavorable. Although several thousand *C. macellaria* adults emerged, their number was small compared to that of the larvae that had developed. Furthermore, many of the flies that did emerge were unable to unfold their wings and properly harden their bodies. It is doubtful whether any of the flies that emerged from this carcass were able to reproduce, because of the low temperatures to which they were subjected.

The mean atmospheric temperature from January 16 to 31 was 47.3 degrees F. A minimum of 19 degrees was recorded on January 19. The mean atmospheric temperature from February 1 to 15 was 50.0 degrees. The maximum temperature recorded during this period was 85 degrees. *Cochliomyia macellaria* was never active in appreciable numbers, as its population had been reduced by the unfavorable weather conditions. *Phormia regina* constituted 95 to 99 per cent of the flies active at carcasses and consequently bred in large numbers during February.

SUMMARY.—From observations in southwestern Texas and southern Arizona during the winters of 1935–36 and 1936–37 it was found that carcasses showed temperatures considerably higher than those of the atmosphere. Such temperatures were due partially to heat absorbed from the sun but principally to heat generated by blowfly larvae which were developing in the carcasses. Temperatures 70 degrees (Fahrenheit) above those of the atmosphere were observed in certain parts of carcasses and more than 50 degrees above in larval masses. The heat generated by blowfly larvae in carcasses enables the larvae to continue to develop and the species to survive periods when weather conditions are unfavorable to adult activity.

Observations on the minimum temperatures at which various species of blowflies become active about carcasses showed that 40 to 50 degrees F. is the range for *Cynomya cadaverina* Rob.-Desv., 50 to 55 degrees for *Lucilia sericata* Meig., and 50 to 60 degrees for certain carcass-breeding species of *Sarcophaga*, 40 to 50 degrees for *Calliphora* spp., 41 to 50 degrees for *Phormia regina* Meig., and 55 to 60 degrees for *Cochliomyia macellaria* F. The influence of other factors, such as cloudiness, humidity, wind, and time of day, probably determine the range of the minimum temperatures at which blowflies become active.

In small carcasses, such as those of jackrabbits, lambs, cats, and small dogs, blowfly larvae were not able to generate and maintain heat sufficiently above atmospheric temperatures during the winter to afford favorable conditions of development.—8-21-39.

# Particle Size of Commercial Lead Arsenate by Sedimentation Analysis

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In previous papers, results by the method of sedimentation analysis have been given for the particle-size distribution of commercial calcium arsenates (Goodhue, 1937) paris greens (Goodhue and Gooden, 1937), and insecticidal sulfurs (Goodhue, 1938). In continuation of this study of commercial insecticides the particle-size distribution of nine brands of lead arsenate has been determined, and the results are reported in this paper.

The method of sedimentation analysis was essentially that described by Goodhue and Smith (1936) but, instead of the original apparatus the modification of Goodhue and Gooden (1939) was used.

The sedimentation medium was 50 per cent ethyl alcohol and the dispersing agent was gum arabic. The sample was dispersed by the revolving-brush method described for the dispersion of sulfur (Goodhue, 1938). Two grams of lead arsenate was weighed into the dispersing apparatus, and 10 cc. of a 2-per cent solution of gum arabic was introduced. The brush was run for 2.5 minutes at 600 r.p.m. for the dispersion of all samples. This standard procedure probably gave different samples, the loose bulking value was determined.

The results, summarized in table 1, show that commercial lead arsenates are very finely divided powders. The particle size varies considerably, but is mostly below a diameter of 2 microns. The coarsest lead arsenate sample is at least as fine as the finest calcium arsenate (Goodhue, 1937) and much finer than the finest paris green sample (Goodhue and Gooden, 1937) studied by this method. The samples contain from 10.5 to 60.3 per cent of material below a diameter of 1 micron. This minute fraction is almost colloidal in nature and will remain in suspension in the sedimentation apparatus for a week or more. No samples specially treated to reduce the particle size were examined.

**Table 1.—The particle-size distribution, density, and loose bulking value of samples of commercial lead arsenate.**

| Sample No. | Percentage Between Indicated Diameters | | | | | | | | Density g. per cc. | Bulking Value cu. in. per lb. |
|---|---|---|---|---|---|---|---|---|---|---|
| | Above 40 microns | 40–20 microns | 20–10 microns | 10–6 microns | 6–4 microns | 4–2 microns | 2–1 microns | Below 1 micron | | |
| 1 | 0.0 | 0.9 | 3.4 | 7.2 | 9.0 | 27.0 | 26.5 | 26.0 | 5.89 | 72.2 |
| 2 | 0.0 | 1.0 | 2.1 | 2.1 | 1.5 | 18.3 | 38.7 | 36.3 | 5.86 | 85.0 |
| 3 | 0.3 | 0.6 | 4.5 | 3.6 | 8.9 | 37.0 | 34.6 | 10.5 | 5.85 | 86.3 |
| 5 | 0.3 | 0.6 | 4.0 | 1.8 | 8.7 | 28.0 | 35.2 | 21.4 | 5.88 | 81.2 |
| 7 | 0.0 | 0.6 | 1.8 | 1.8 | 6.3 | 16.8 | 40.2 | 32.5 | 5.99 | 80.8 |
| 8 | 0.3 | 0.6 | 4.7 | 1.0 | 4.7 | 17.1 | 24.8 | 46.8 | 5.90 | 85.8 |
| 9 | 0.0 | 0.3 | 3.1 | 5.0 | 8.4 | 27.3 | 42.5 | 13.4 | 5.92 | 68.4 |
| 11 | 0.0 | 0.6 | 1.2 | 3.0 | 6.6 | 24.6 | 28.8 | 35.2 | 5.74 | 92.5 |
| 12 | 2.0 | 0.3 | 3.3 | 5.0 | 2.0 | 18.9 | 39.5 | 29.0 | 5.90 | 64.5 |
| 14 | 0.0 | 0.0 | 4.7 | 7.1 | 10.5 | 24.5 | 15.0 | 38.2 | 5.85 | 57.0 |
| 15 | 0.6 | 0.3 | 2.7 | 5.7 | 7.0 | 16.5 | 30.6 | 36.6 | 5.95 | 79.5 |
| 16 | 1.5 | 0.6 | 0.6 | 3.8 | 3.6 | 6.2 | 23.4 | 60.3 | 5.90 | 130.0 |

After dispersion the suspension was quantitatively transferred to the sedimentation apparatus and the settling process studied in the usual manner. The scale reading was plotted against time, and the particle-size distribution was determined by the graphic method of Odén (1916).

In the calculation of particle-size distribution it was necessary to know the absolute densities of all samples. These values were determined by the pycnometer method described in the previous papers. Also, to show the fluffiness of the comparative results, even though complete dispersion may not have been attained.

The loose bulking value of the various lead arsenates is not well correlated with the particle size, as judged by the large proportion below 2 microns in diameter. The finest sample (No. 16) has the highest bulking value, but the coarsest sample (No. 3) does not have the lowest value. Except for No. 16, the bulking value does not give an indication of the particle size. —8-18-39.

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# Rearing of Mosquito Larvae and Effect of Diet on Their Resistance to Rotenone and Nicotine

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Mosquito larvae have been used for a number of years in insecticide-testing laboratories as convenient material for tests to estimate the toxicity of compounds thought to have insecticidal action. They have been widely used because of the ease with which they can be obtained and reared rather than because of any particular superiority as indicators of general toxic action. During the last few years a great many synthetic organic compounds and plant extracts have been tested on mosquito larvae and their relative insecticidal value estimated on the basis of such tests.

Since mosquito larvae hold such an important place in the field of insect toxicology, it was considered important to investigate the possible factors which may influence their resistance to insecticides. This paper describes the authors' technique for rearing and testing larvae of *Culex quinquefasciatus* Say and the influence of diet on the resistance of the larvae to rotenone and to nicotine. All the work was carried on at Sanford, Fla., in the laboratory of the Division of Control Investigations of the Bureau of Entomology and Plant Quarantine, United States Department of Agriculture.

The technique described herein is a modification of that described by Campbell *et al.*, (1933) and Fink *et al.* (1938). Changes have been made in the diet fed the larvae by these workers and in various details of their rearing technique. A few changes have also been made in the methods of testing samples for toxicity.

COLLECTION OF EGGS.—No attempt was made to rear the insect through its entire life cycle because field-collected eggs could be obtained in sufficient numbers throughout the year. The egg clusters, or rafts, were collected each morning from tubs of water containing a small amount of baker's yeast and blood albumin. These tubs were kept in a sheltered location out of doors. When the number of rafts desired for the rearing work had been taken from the tubs, those remaining were scooped out and discarded, together with all floating debris.

REARING THE LARVAE.—Various culture media have been used in rearing mosquito larvae. Marcovitch (1928) used dried blood as a food medium, but Campbell *et al.* (1933) found baker's yeast more satisfactory than the dried blood. The writers have used a number of media but have found a modification of the mixture of baker's yeast and dried blood described by Fink *et al.* (1938) very satisfactory on account of the rapid rate of growth of the larvae and the lack of scum on the rearing jars. Since the development of scum is an effect of environmental conditions, it is possible that this medium would not prove satisfactory in every locality. It has been reported to be unsatisfactory at the National Agricultural Research Center, Beltsville, Md., because of this difficulty.*

The rearing jars and test beakers were held at a temperature of approximately 28 degrees C. in a water bath 70 inches long, 30 inches wide, and 18 inches deep. The rearing containers used were glass battery jars 6 inches in diameter with a capacity of approximately 1 gallon. About 3 quarts of water were placed in each jar and 12 to 15 clusters of eggs were placed on the surface of the water. The jars containing the eggs were then dated and kept in the water bath; the eggs usually hatched within about 24 hours after the jars were placed in the bath. In the procedure that had been generally followed by the writers, 4 cc. of a stock suspension

* From unpublished notes by W. N. Sullivan, Beltsville, Md.

of yeast and 1 cc. of stock solution of blood albumin were then added to each jar. Two days later 8 cc. of the yeast suspension and 2 cc. of the blood albumin solution were added to each jar. A like amount was again added on the fourth day, making a total of 20 cc. of the yeast suspension and 5 cc. of the blood solution used in each jar. The stock suspension of yeast contained 1 pound (approximately 450 grams) of baker's yeast per liter of water. The stock solution of blood albumin was made by dissolving 20 grams of the commercial powder, 95 per cent soluble, in 200 cc. of water. To aid in the dissolution of the lumpy particles, this mixture was kept in a beaker at room temperature for 2 days before it was used, after which time it was kept in the refrigerator. The larvae grew faster and were more uniform when the yeast and blood albumin were added to the jars containing the larvae in small portions, and at intervals, as stated above, than when the full amount was added at one time. With 12 to 15 clusters of eggs in each jar, the population would average between 2,500 and 3,000 larvae. With the population, food, and temperature as described, the larvae grew to the fourth instar in 5 to 7 days, at which time they were used in tests.

PROCEDURE FOR TESTING INSECTICIDES.—The fourth-instar larvae were removed from the rearing jars with a cheesecloth net which was immediately held over the sink and the larvae gently washed with distilled water. They were then removed from the net by turning it over and touching it to distilled water in a shallow, white-enameled pan, where they quickly swam free. When larvae were taken from more than one jar they were mixed together in this pan so that larvae could be taken at random from the mixture for each test. Groups of 50 larvae were then dipped out of the pan by means of a cheesecloth net approximately 1 inch in diameter and put into 100-cc. beakers containing 25 cc. of distilled water.

The tests were made in beakers containing 100 cc. of distilled water and the sample of insecticide to be tested at the concentration desired. In preparing a sample for testing, 25 cc. of distilled water was poured into each of two 100-cc. beakers, and the sample of insecticide to be tested was added to each by means of a pipette. An additional 50 cc. of distilled water was then added to each beaker, thus producing a stirring effect and mixing the sample with the water. The 25 cc. of water containing the larvae was then poured into these beakers, bringing the volume up to 100 cc. and introducing the 50 larvae to start the test. The beakers were then kept in the water bath for 18 hours with the temperature still at 28 degrees C.

At the end of the 18-hour period the beakers were removed from the bath to a work table and the larvae were examined for possible mortality. This was done by again counting the number of larvae in the beaker, after which the number of dead larvae was determined by lifting each individual to the surface of the water by means of a slender glass rod bent at an angle of 30 degrees one-half inch from the end. When no movement was evident as the larva was lifted the individual was considered dead. Each test was made on a total of 100 larvae.

EFFECT OF DIET.—Variations in the resistance of different groups of larvae are very evident, even with the standardized conditions of rearing just described. In the course of previous work it has been found that the results of different tests on the same lot of larvae might vary as much as 30 to 40 per cent and that tests might vary as much as 50 per cent on different lots of larvae reared, over a period of time, on the same diet. The reason for this is undoubtedly a physiological one, brought about by the different reaction of individual organisms to what appears to be a similar treatment. The factors which influence this physiological condition are not entirely understood at the present time, but it seemed probable that the kind and quantity of food eaten would have a direct influence on the constitution of the larvae. With this assumption in mind the authors decided to attempt to rear groups of larvae that would display, respectively, a maximum and a minimum resistance to a given insecticide. Diet was selected as the factor most likely to achieve this result, so the present experiments were limited to this phase of the problem.

Ten media were tested in 30 different concentrations and combinations, but the results do not warrant any very definite conclusions as to their comparative value. As a matter of fact, the results tend to show that variations in larvae are more

quickly produced by a quantitative manipulation of the diet than by a qualitative one. Weak larvae could be produced with almost any diet by providing just enough food to keep the larvae alive, whereas increasing the quantity of food caused more rapid growth and, to a certain extent, stronger larvae.

Effects of five representative diets are reported in table 1, and these serve to illustrate the range of resistance encountered in this series of tests. A short description of the various diets listed in the table, to give in detail the form in which the materials were used and the method of preparation, follows.

(1) *Hay infusion.* Dry grass was steeped in a tub of water out of doors for 7 days. The tub was half filled with grass and just sufficient water added to cover the grass. This material was then diluted with rain water to produce the concentrations shown in the table.

(2) *Brewer's yeast.* Measured quantities of the commercial dry yeast powder were mixed into a thin paste and added to the jars as desired.

(3) *Baker's yeast and blood albumin.* A stock suspension was made by mixing together 4 parts, by volume, of a yeast suspension and 1 part of a blood albumin solution. These were made up as previously described under the rearing technique.

(4) *Baker's yeast.* A stock suspension was prepared by mixing approximately 450 grams of baker's yeast in a liter of water.

(5) *Pablum.* This is a commercially prepared dry cereal and was added to the jars in the form of a thin paste in water.

Most of the diets used produced satisfactory larvae for testing purposes. Several of the diets, however, were in the upper limits of concentration and caused considerable mortality in the rearing jars as a result. A diet of baker's yeast alone did not always produce uniform larvae, as there was usually a tendency for some individuals to grow faster than others. This was also found true in the case of several diets not listed in the table, such as pure starch and the commercial preparation "*Dextri-maltose.*" Starch caused the greatest fluctuation in growth, an estimated 60 per cent of the larvae changing to the fourth instar in 24 to 25 days while the remaining 40 per cent were still in the second and third instars.

RESISTANCE TO ROTENONE AND NICOTINE.—The compounds tested to indicate variations in the resistance of the larvae were rotenone and nicotine. A stock solution of pure rotenone was made up in acetone so that measured quantities could be added to the test beakers by means of a pipette. The stock solution of nicotine was made by diluting the pure sample with water. In the present series of tests rotenone was always used at a concentration of 5 parts per million, by weight, and nicotine at 100 parts per million, by volume.

Table 1 shows the reaction of field-collected larvae as well as of laboratory-reared individuals to rotenone and nicotine. The mortality in check tests made with the various lots of larvae held in distilled water for 18 hours was never more than 2 or 3 per cent. In six different tests with field-collected larvae the average kill with rotenone was 72 per cent and with nicotine, 78 per cent. These tests form a basis for comparison of the laboratory-reared stock.

The three concentrations of hay infusion are good examples of the effect of quantitative manipulation of the diet. In the case of rotenone, a difference of 76 per cent was found between the mortality averages for the 5 per cent and 100 per cent media, and a corresponding difference of 79 per cent was found in the case of nicotine. Among the individual tests with larvae reared on hay infusion there was found a variation of 90 per cent in the mortality to rotenone and 92 per cent to nicotine. With regard to resistance, it is of interest to note that no better diet than hay infusion was found in this series of tests. It should also be pointed out that 15 per cent mortality, or 85 per cent survival, would seem to represent the average uppermost limit of resistance of this species to rotenone and nicotine at the concentrations used. A few individual tests have shown larvae more resistant than this, but the average of several tests tends to establish the 15 per cent limit.

Brewer's yeast is also an excellent diet and tolerates even more dilution than the hay infusion. Where a dilution to 1 to 20 of the hay infusion caused a difference of 76 per cent in the mortality with rotenone a dilution of 1 to 80 in the yeast changed

the mortality only 22 per cent. The figures for nicotine show a greater variation than those for rotenone, which leads to the conclusion that the two compounds have a different physiological action and therefore may not be resisted to the same degree. With regard to rate of growth, the 5 per cent hay infusion and the one-fourth-gram diet of brewer's yeast are about the same. Despite this and the fact that the larvae appear quite similar, the mortality caused by the two insecticides shows the two lots of larvae to be physiologically dissimilar.

The most resistant larvae obtained with the yeast and blood medium were only slightly more resistant than those reared on the lowest brewer's yeast concentration. It is believed that the 20-cc. concentration is about the greatest that could be tolerated by the larvae. The 5-cc. concentration brought about the same rate of growth, which suggests that the 20-cc. concentration is in excess of the required amount. The explanation of the lower mortality figures for the 20-cc. concentration may lie in the fact that all the weaker larvae were killed by the high concentration of food in the rearing jar. In other words, it is suspected that the increased food added little to the larvae physiologically but rather brought about a natural selection by unfavorable environmental conditions.

It is evident from the table that rotenone and nicotine, at the concentration used, will kill approximately 50 per cent of the most resistant larvae that can be reared on baker's yeast or *Pablum*. Concentrations in excess of 5 cc. of yeast apparently have little effect in increasing growth or producing more resistant larvae. The concentration of *Pablum* could not be further increased because of the development of scum in the more concentrated media.

**Table 1.—The effect of diet on the resistance of mosquito larvae to rotenone and nicotine, Sanford Fla., 1938.**

| Diet | Amount Used* | Age in Days to 4th Instar | Number of Tests | Rotenone 5 p.p.m. Per Cent Kill after 18 Hrs. | Rotenone 5 p.p.m. Standard Deviation | Nicotine 100 p.p.m Per Cent Kill after 18 Hrs. | Nicotine 100 p.p.m Standard Deviation |
|---|---|---|---|---|---|---|---|
| (Field-collected larvae) | | | 6 | 72 | 2.8 | 78 | 1.9 |
| Hay Infusion | 100 per cent | 4 | 4 | 15 | 3.0 | 18 | 4.0 |
| Hay Infusion | 50 per cent | 4 | 5 | 59 | 11.6 | 75 | 7.7 |
| Hay Infusion | 5 per cent | 9 | 4 | 91 | 1.3 | 97 | 1.1 |
| Brewer's yeast | 10 grams | 4 | 4 | 16 | 7.0 | 17 | 9.6 |
| Brewer's yeast | 6 grams | 4 | 4 | 28 | 10.5 | 33 | 9.6 |
| Brewer's yeast | 2 grams | 4 | 7 | 17 | 4.2 | 26 | 5.4 |
| Brewer's yeast | 1 gram | 5 | 5 | 15 | 3.7 | 20 | 3.2 |
| Brewer's yeast | ½ gram | 9 | 5 | 37 | 6.7 | 55 | 4.5 |
| Brewer's yeast | ¼ gram | 13 | 3 | 38 | 3.5 | 62 | 2.3 |
| Yeast and blood | 20 cc. | 6 | 3 | 35 | 11.2 | 23 | 1.5 |
| Yeast and blood | 15 cc. | 6 | 3 | 31 | 7.8 | 39 | 11.5 |
| Yeast and blood | 10 cc. | 6 | 3 | 44 | 4.3 | 32 | 10.0 |
| Yeast and blood | 5 cc. | 6 | 3 | 48 | 5.7 | 53 | 3.0 |
| Yeast and blood | 1 cc. | 14 | 3 | 57 | 21.1 | 64 | 13.3 |
| Yeast and blood | .5 cc. | 19 | 5 | 90 | 2.2 | 87 | 4.5 |
| Baker's yeast | 25 cc. | 8 | 4 | 80 | 3.5 | 56 | 10.9 |
| Baker's yeast | 5 cc. | 8 | 6 | 49 | 6.9 | 45 | 6.2 |
| Pablum | 3 grams | 5 | 4 | 55 | 5.0 | 53 | 8.1 |
| Pablum | 1 gram | 6 | 2 | 66 | 0.0 | 77 | 1.0 |
| Pablum | ¼ gram | 8 | 6 | 71 | 10.5 | 86 | 5.2 |

* The quantities listed were added to the 3 quarts of water in each jar on the first day after the eggs had hatched. Twice these amounts were added every other day thereafter to the fourth instar except that when the hay infusion was used the entire medium was changed.

In only one individual test was the resistance to the two insecticides absolute. The larvae used in this test were reared on the 10-gram medium of brewer's yeast, but it is probable that the superior resistance was brought about by the mortality of the weaker individuals in the concentrated food medium. At the other extreme, individual tests ran as high as 98 per cent killed from both insecticides, but in no case was mortality complete. It would appear, therefore, that mosquito larvae can be reared by artificial methods to show almost complete susceptibility or complete resistance to rotenone and nicotine at the concentrations here used.

From the series of tests that have been made it is clear that available food is not the only factor influencing resistance. Considerable variation will be present even when the food medium and the temperature are accurately controlled. (Hereditary influences may be responsible for a part of this, but the nature of the other factors which may be involved has not yet been explained.

SUMMARY.—A convenient and economical method of rearing and testing mosquito larvae is described.

A brief study was made of the relative resistance of larvae reared on a number of different diets, and it was found that resistance to rotenone and nicotine could be controlled to a very large extent by artificial methods of rearing, especially in the quantity or concentration of food supplied.—9-6-39.

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# Methyl Bromide Fumigation for Destruction of Pod Borer Larvae

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*Maruca testulalis* Geyer, a bean pod borer, has long been known to occur in the West Indies, Central America, Mexico, Hawaii, and elsewhere, but is not known in the United States. The importation of vegetable products which might be infested with larvae of this insect is allowed only during the winter months, and each shipment must pass inspection at the port of entry or, if shipped from Puerto Rico, be certified at San Juan by representatives of the Bureau of Entomology and Plant Quarantine. At the beginning of the winter of 1938–39 any shipment (a lot under one customs-entry mark) found infested was refused entry, thus causing considerable loss to importers. In an effort to salvage these infested shipments the importers agreed to make them available to the Bureau for experimental studies with methyl bromide. These studies were carried on at New York City and at San Juan, P. R., from November 1938 to April 1939.

After preliminary trials had shown lima bean pods to be uninjured by methyl bromide, infested shipments were fumigated at New York at a deliberately selected high dosage, reinspected, and released when no larvae were found to be alive. This experimental procedure was continued throughout the winter of 1938–39. In February and March 1939 comprehensive studies were made in Puerto Rico to determine the lethal dosages of methyl bromide at (1) normal temperatures (above 70 degrees F.) and at both atmospheric pressure (atmospheric fumigations) and reduced pressure (vacuum fumigations) and (2) low temperatures (below 70 degrees F.) and at reduced pressure (vacuum fumigations).

The first objective was to determine the feasibility of fumigating green pod vegetables at the point of origin before shipping and the second to determine the effectiveness of fumigation at destination under the adverse temperature conditions encountered at New York during the winter. Tests on the latter objective were

confined to vacuum fumigation since it was speedier and equipment was available in New York. As pod vegetables freeze readily at 32 degrees F, fumigations at this point or below were not considered. Further tests of the effect of fumigation on the quality of green pod vegetables were also made.

The experiments in New York were made at a commercial fumigating plant and those in Puerto Rico in an experimental fumigator. Low temperatures were obtained by placing the fumigating equipment in a cold room at a pre-cooling plant. In vacuum fumigations the gas was introduced into a 15-inch vacuum, which was maintained for the duration of the treatment.

In Puerto Rico all mortality tests were made with string beans infested with *Maruca testulalis* and in New York with infested green lima beans. The habits of *M. testulalis* larvae are apparently similar on all pod vegetables that they attack and therefore the results obtained were considered applicable to the hosts mentioned.

VACUUM FUMIGATIONS AT TEMPERATURES BETWEEN 75 AND 85 DEGREES.—Low dosages were found to be effective under vacuum conditions. Ninety-minute durations had previously proved effective at reduced pressure and were used in these experiments. Fumigations were begun with a maximum dosage of 3 pounds of methyl bromide per 1,000 cubic feet of space including the load (hereinafter designated as 3 lb./1000) and the dosage was gradually decreased to a point where some insects survived, which was 0.25 lb./1000. Three tests with 0.5 lb./1000 produced complete mortality, as did two tests each with 1 lb./1000, 1.5 lb./1000, and 2 lb./1000. In one test each with 0.5 lb./1000 and 1 lb./1000 infested pods were layered in the center of a 1-bushel shipping crate of string beans packed in regulation style and no insects survived. The results of these tests are shown in table 1.

ATMOSPHERIC FUMIGATIONS AT TEMPERATURES BETWEEN 75 AND 80 DEGREES.—Two-hour fumigations at normal pressure proved to be as effective as 90-minute fumigations with vacuum. Tests were begun with a maximum dosage of 3 lb./1000 and the quantity of methyl bromide gradually decreased to the lowest effective dosage under vacuum conditions with comparable temperature limits, and all caused complete mortality. One test with 0.5 lb./1000, two with 1 lb./1000, one with 1.5 lb./1000, one with 2 lb./1000, and one with 2.5 lb./1000 were found to be effective.

VACUUM FUMIGATIONS AT TEMPERATURES BELOW 70 DEGREES.—Vacuum fumigations were made in San Juan at precooling temperature (41 degrees F.) with 1 lb./1000 to 2.5 lb./1000 and it was found that larger dosages were necessary than at higher temperatures. In two tests out of three some insects survived fumigation with 1 lb./1000 and in two out of three with 1.5 lb./1000, but none survived after one fumigation with 2.5 lb./1000. The results of these tests are given in table 1.

**Table 1.—Mortality of *Maruca testulalis* larvae in string bean pods resulting from 90-minute fumigations with methyl bromide in a 15-inch vacuum, San Juan, Puerto Rico, February, 1939.**

| DOSAGE LBS. PER 1,000 CU. FT.) | TEMPERATURE, DEGREES F. | NUMBER OF LARVAE | | PER CENT MORTALITY |
|---|---|---|---|---|
| | | Dead | Alive | |
| | Normal temperatures | | | |
| 0.25 | 80 | 11 | 5 | 69 |
| 0.50 | 80 | 22 | 0 | 100 |
| 0.50 | 80 | 23 | 0 | 100 |
| 0.50* | 77 | 51 | 0 | 100 |
| 1.00 | 80 | 23 | 0 | 100 |
| 1.00* | 77 | 71 | 0 | 100 |
| 1.50 | 77 | 15 | 0 | 100 |
| 1.50 | 78 | 25 | 0 | 100 |
| 2.00 | 80 | 45 | 0 | 100 |
| 2.00 | 77 | 29 | 0 | 100 |
| 2.50 | 82 | 11 | 0 | 100 |
| 3.00 | 80 | 18 | 0 | 100 |
| | Low temperatures | | | |
| 1.00 | 41 | 30 | 3 | 91 |
| 1.00 | 41 | 44 | 0 | 100 |
| 1.00 | 41 | 6 | 24 | 20 |
| 1.50 | 41 | 5 | 1 | 83 |
| 1.50 | 41 | 68 | 0 | 100 |
| 1.50 | 41 | 36 | 8 | 82 |
| 2.00 | 55 | 22 | 0 | 100 |
| 2.50 | 42 | 2 | 0 | 100 |

* Infested beans layered in center of loaded crate.

In New York, eight commercial shipments were examined following fumigations with 4 lb./1000 at temperatures between 34 and 57 degrees and no live insects were found (table 2).

EFFECT OF FUMIGATION ON THE HOST VEGETABLES.—Fumigation tests were made with green lima beans, pigeon peas

(*Gandules*), and string beans at both normal and low temperatures to determine the effect of methyl bromide on these vegetables.

Tests were made with imported lima beans that had been kept at a storage temperature of 50 degrees or less for at least 1 week and with beans that were freshly picked and uncooled. Dosages as high as 5 lb./1000 were used and the pods were apparently unaffected. In two trial shipments from San Juan to New York following fumigation the beans were not adversely affected. In New York 11,590 1-bushel hampers of imported lima beans were fumigated between November 1938 and April 1939 without decrease in their market value.

**Table 2.—Mortality of *Maruca testulalis* larvae in lima bean pods resulting from 90-minute fumigations of methyl bromide at the rate of 4 pounds per 1,000 cubic feet in a 15-inch vacuum, at dock temperatures, New York City, 1938–39.**

| Date | Temperature of Pods, Degrees F. | Number of Hampers Examined | Number of Larvae | | Per Cent Mortality |
|---|---|---|---|---|---|
| | | | Dead | Alive | |
| Dec. 6 | 51–57 | 40 | 30 | 0 | 100 |
| 14 | 41–45 | 43 | 16 | 0 | 100 |
| 21 | 40–45 | 21 | 1 | 0 | 100 |
| 28 | 50 | 11 | 3 | 0 | 100 |
| Jan. 4 | 40–43 | 33 | 5 | 0 | 100 |
| 11 | 50 | 29 | 9 | 0 | 100 |
| 18 | 38 | 16 | 2 | 0 | 100 |
| 25 | 34–40 | 37 | 7 | 0 | 100 |

In a trial shipment from San Juan to New York following fumigation with 2 lb./1000, pigeon peas showed some deterioration of pods in the center of the crate. As this condition often occurs in shipping this product it cannot be attributed definitely to fumigation. In April 1939, 97 crates of imported, refrigerated pigeon peas were fumigated in New York with 2.5 lb./1000 without any observed injury.

Uncooled string beans were injured by dosages of 3 lb./1000 and above. The injury appeared as brownish, pitted spots on the pods. Such injury was found to a slight degree on beans fumigated with 2 lb./1000 and stored in a household electric refrigerator. In two trial shipments from San Juan to New York following fumigation with 2 lb./1000, however, the beans were in excellent condition upon arrival. No commercial importations were fumigated.

COMMERCIAL APPLICATION.—The foregoing tests are considered as sufficient basis for the use of methyl bromide fumigation in the commercial treatment of green pod vegetables actually or potentially infested with larvae of *Maruca testulalis*, especially since part of the experiments proved successful on a commercial basis. Since the goal of plant quarantine regulation is to eliminate the hazard of pest introduction, dosages nearer the limit of host tolerance than the minimum needed for pest eradication should be used so as to allow sufficient margin for unanticipated irregularities that often occur in treating large quantities of material.

In commercial treatments the dosage should be not less than 1.5 lb./1000, either in a 15-inch vacuum for 90 minutes or at atmospheric pressure for 2 hours, where the temperature of the product and the atmosphere is 70 degrees F. or above, and not less than 3 lb./1000 in a 15-inch vacuum where temperatures below 70 degrees prevail or when the product has been precooled or exposed to winter temperatures.

It is essential that fumigated vegetables be aired for several hours following treatment to allow absorbed gas to dissipate, otherwise injury is likely to occur during subsequent storage or transit. This is especially important where crated material is shipped in refrigerated holds without forced ventilation.

Methyl bromide is a poison, and an operator should use an approved gas mask when exposed to the gas at concentrations used in fumigation.

SUMMARY.—Experimental studies at New York City and San Juan, P. R., from November 1938 to April 1939 showed that larvae of *Maruca testulalis* Geyer can be killed by fumigation with methyl bromide. Fumigation at dosages as low as 0.5 pound per 1,000 cubic feet caused complete mortality at normal temperatures (above 70 degrees F.) either in a 15-inch vacuum for 90 minutes or under atmospheric pressure for 2 hours. At low temperatures high dosages of the fumigant were required.

Green lima beans, pigeon peas and string beans were uninjured at dosages considerably above those needed to kill

the larvae. The first two products were also tested under commercial conditions.

For fumigation of commercial shipments 1.5 pounds of methyl bromide per 1,000 cubic feet should be used at temperatures above 70 degrees, either in a 15-inch vacuum for 90 minutes or at atmospheric pressure for 2 hours, and 3 pounds per 1,000 cubic feet for 90 minutes in a 15-inch vacuum for temperatures below 70 degrees.—10-9-36.

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# Field Biology and Environmental Relationships of the Gulf Coast Tick in Southern Georgia*

HOMER HIXSON†

Although it has been known since 1912 that the Gulf coast tick, *Amblyomma maculatum* Koch, creates conditions in the ears of domestic animals which induce screwworm infestations, its importance in this respect was not fully realized until the recent outbreak of the screwworm in the southeastern section of the United States. The influence of ticks in this epizootic was shown to be predominant by the Screwworm Control Division of the Bureau of Entomology and Plant Quarantine in its classification of the predisposing causes of the screwworm cases examined in 1935. Over 50 per cent of the cases examined in Georgia during August of that year were diagnosed as originating at the site of injuries caused by ticks. The lack of management of range animals was responsible for the high tick incidence; consequently, the large number of animals predisposed by ticks was the added factor that accounted for the unusual abundance and activity of the screwworm fly.

The Gulf coast tick has been considered of small moment as a parasite, but this indirect cause of heavy losses to the livestock industry has emphasized the necessity of its control. To investigate the possibilities of winter-burning of range areas, host eradication, and ear-treatment of domestic animals as methods of control, a detailed knowledge of the life history and habits, and environmental relationships was necessary. Consequently, the information presented in this paper was sought with that point of view. The study extended over the period from September 1935 to December 1936.

LITERATURE.—General knowledge of the Gulf coast tick has been reviewed by Robinson (1926) and Bishopp & Hixson (1936). Contributions to the host list for the United States have been made by Hunter & Hooker (1907), Bishopp (1912), Hooker, Bishopp & Wood (1912), and Bishopp & Hixson (1936). Life history studies have been made by Hunter & Hooker (1907), Hooker (1908), Newstead (1909), Hunter, Bishopp & Wood (1912), and Bishopp & Hixson (1936).

BIOLOGY AND ENVIRONMENTAL RELATIONSHIPS.—The Gulf coast tick is a three-host species that is well adapted to the conditions of its restricted range.

METHOD OF APPROACH.—Basic information concerning the parasitic activity of the different stages of the Gulf coast tick in the field was obtained by frequent examinations of principal hosts that were ranging areas known to have high tick populations. Sheep were examined regularly for adults, and meadowlarks were collected and examined during biweekly intervals for the immature stages.

As a complement to field investigations, contemporaneous studies were made at the laboratory with each biological form on its principal host and in small outdoor enclosures which were constructed in a plant association characteristic of the natural habitat of the tick, in order that engorgement, adjustment, development, and longevity might correspond with that of the same forms extant in nature.

OUTDOOR ENCLOSURE.—The outdoor enclosure was constructed with four 8″×12″ glass window panes set in the

* Taken from a thesis submitted to the faculty of the Graduate College of Iowa State College, in partial fulfillment of the requirements for the degree, doctor of philosophy.

The investigational part of the work represented in this paper was done while the author was in the service of the United States Department of Agriculture, Bureau of Entomology and Plant Quarantine, Division of Insects Affecting Man and Animals.

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soil in such a fashion that one edge of each pane was flush against the side, near one end of another. Each pane stood in the same relative position, forming an open top enclosure approximately six inches high and a little less than a foot square. The panes were fitted so closely together that it was impossible for any form of this tick to escape at their junctures. A ridge of white petrolatum was smeared along the rim to prevent the imprisoned forms from crawling over the top. To prevent bridging-over, the tall vegetation was kept clipped, but the arrangement of the low vegetation was not disturbed.

**Table 1.—Periodic incidence of the adult Gulf coast tick on thirty regularly examined sheep in 1936.**

| Date Examined | Number of Ticks | | | Percentage of Animals Infested With | |
|---|---|---|---|---|---|
| | Males | Females | Engorging | Males | Females |
| April 28 | 6 | 1 | 0 | 20 | 0 |
| May 12 | 26 | 8 | 1 | 60 | 23 |
| May 27 | 26 | 5 | 1 | 67 | 17 |
| June 9 | 42 | 16 | 3 | 90 | 23 |
| June 23 | 42 | 16 | 4 | 97 | 37 |
| July 7 | 53 | 74 | 46 | 97 | 73 |
| July 20* | 115 | 165 | 105 | 100 | 73 |

* Summation of data taken July 13 and 20.

PREOVIPOSITION AND OVIPOSITION.—The replete female is active from the time it drops from the host until it conceals itself on the surface of the soil under vegetation, bark or other rubbish. As soon as the location for oviposition is established, it remains inactive during the remainder of the preoviposition period. The duration of this period varies from four to six days, almost without exception, under conditions prevailing during the period of normal host-seeking activity.

The gravid female oviposits on the surface of the soil, but occasionally prepares a shallow excavation. The number of eggs varies considerably, apparently depending on the size of the replete tick. An unusually large female, measuring 18×13×10 mm., deposited 18,497 eggs. This record and comparative studies strongly indicate that the average number of eggs deposited by this species is much greater than previously reported.

INCUBATION.—The incubation period normally ranges from 19 to 50 or 60 days or it may extend through the winter. During the greater part of the season, however, 19 to 28 days is the normal range. Only eggs deposited during the latter part of September and thereafter require a longer period.

The threshold of development is relatively high and the rate of embryonic development, which is controlled by temperature, fluctuates considerably within a narrow range. Variations in vegetative cover, even within a square foot of space, may vary the temperature sufficiently to cause considerable difference in the time required for incubation.

REPRESENTATIVE DATA ON PREOVIPOSITION, OVIPOSITION AND INCUBATION.—In field studies, about a month was indicated as the total time required for preoviposition, oviposition and incubation. The length of the combined periods is based on the interval between the increase in the incidence of adult engorgement and the increase of larval incidence. Laboratory studies confirm this indication.

In incidence studies, the percentage of sheep infested with ticks of both sexes and the number of females engorging, increased substantially during the latter part of June and early July as shown in table 1. The incidence of larvae on meadowlarks made a corresponding increase during the latter part of July and early August as shown in table 2.

Development did not advance to the larval stage from two engorged females that were placed in an outdoor enclosure

**Table 2.—Initial incidence increase of the Gulf coast tick larva on meadowlarks in 1936.**

| Period of Collection | Birds | | Larvae | |
|---|---|---|---|---|
| | Number Collected | Percentage Infested | Ave. No. Per Infested Bird | Calculated No. Per 100 Birds |
| July 5–12 | 7 | 0 | 0.0 | 0 |
| July 13–20 | 10 | 20 | 2.5 | 50 |
| July 21–28 | 9 | 78 | 10.7 | 831 |
| July 29–Aug. 5 | 8 | 88 | 18.2 | 1592 |

June 12, 1936, nor from one similarly placed June 19. The failure to develop, in both cases, is attributed to a dry period that followed the placement of the females.

Two replete females that detached July 30, were placed in an outdoor enclosure. Larvae were active September 3. Seven engorged females that detached August 28, were similarly placed. Larvae were active September 30.

An engorged female that detached Sep-

tember 2, was placed on moist sand in a stender dish in the laboratory. It began oviposition September 6, and hatching began September 25. All eggs in the mass had hatched by October 1.

A replete female that detached September 29, 1935, was placed in an outdoor enclosure which had practically no vegetation. It began oviposition under a piece of bark October 5. Hatching began November 10. A replete female that detached October 1, 1936 and was placed in

congregate on the lower surface of stems, leaves or any nearby object and remain inactive from one to two days. They await the approach of a host in groups, usually concealed in grass stalks that lean out into small open spaces in low vegetation. All observations indicate that larvae are stimulated to activity by animal odor. When they sense the presence of a host, they crawl to the edge of the object on which they are located and extend the forelegs out from the lower side in such a

**Table 3.—Biweekly incidence of the Gulf coast tick larva on meadowlarks in 1935–36.**

| Period of Collection | Birds | | Number of Larvae | | | Maximum Daily Temp. Ave. °F. |
|---|---|---|---|---|---|---|
| | Number Examined | Percentage Infested | Average Per Infested Bird | Maximum Infestation | Per 100 Birds (Calculated) | |
| Oct. 14–27 | 3 | 100 | 32.0 | 65 | 3200 | 80.4 |
| 28–Nov. 10 | 10 | 70 | 45.5 | 289 | 3185 | 81.0 |
| Nov. 11–24 | 16 | 81 | 38.4 | 207 | 3110 | 68.2 |
| 25–Dec. 8 | 20 | 35 | 8.7 | 46 | 304 | 63.7 |
| Dec. 9–22 | 10 | 20 | 1.5 | 2 | 30 | 54.7 |
| 23–Jan. 5 | 20 | 0 | 0.0 | 0 | 0 | 55.8 |
| Jan. 6–19 | 21 | 5 | 1.0 | 1 | 5 | 70.8 |
| 20–Feb. 2 | 25 | 36 | 6.4 | 32 | 205 | 61.9 |
| Feb. 3–16 | 4 | 0 | 0.0 | 0 | 0 | 55.6 |
| 17–Mar. 1 | 4 | 25 | 2.0 | 2 | 50 | 64.8 |
| Mar. 2–15 | 7 | 0 | 0.0 | 0 | 0 | 70.4 |
| 16–June 21 | 72 | 0 | 0.0 | 0 | 0 | 70.0+ |
| 22–July 5 | — | — | — | — | — | 91.7 |
| July 6–19 | 14 | 14 | 2.5 | 3 | 25 | 91.9 |
| 20–Aug. 2 | 13 | 62 | 13.9 | 36 | 862 | 91.2 |
| Aug. 3–16 | 11 | 64 | 13.9 | 42 | 890 | 88.6 |
| 17–Sept. 13 | — | — | — | — | — | 90.0+ |
| Sept. 14–27 | 8 | 75 | 45.8 | 124 | 3435 | 90.7 |
| 28–Oct. 11 | 12 | 42 | 31.8 | 108 | 1335 | 85.2 |
| Oct. 12–25 | 7 | 71 | 28.2 | 133 | 2002 | 83.1 |
| 26–Nov. 8 | 20 | 90 | 13.6 | 105 | 1224 | 77.1 |
| Nov. 9–22 | 17 | 65 | 12.9 | 44 | 838 | 68.4 |
| Nov. 23–30 | 7 | 0 | 0.0 | 0 | 0 | 59.0 |

an enclosure which had a moderate amount of vegetative cover, began oviposition October 8. Hatching began November 24.

Three replete females that detached September 27, 1935, were placed in an outdoor enclosure. One began oviposition October 2. The eggs from this individual were deposited under fairly light vegetative cover. They began hatching November 14. Another female oviposited in a shallow excavation under similar cover. Hatching began November 26. The third female oviposited under heavy vegetative cover. On January 18, the eggs of the latter were still in the early stages of development. It required about two weeks for a few eggs from this mass to hatch after they were placed under favorable conditions in the laboratory. Vegetative cover which acts as a buffer to solar heat, and the cooling effect of the soil, undoubtedly account for these variations in incubation.

THE LARVAE.—Newly hatched larvae

fashion that the border of the object appears densely pubescent. While actively seeking the host, larvae may crawl about individually, but usually they become stationed in small groups at terminal points on the vegetation. After the stimulus has been dispelled, the larvae reassemble in clusters near the station of activity. Through repetition of such activity, the original cluster is gradually dispersed and may spread over an area ten or twelve feet in diameter within a month.

Larval host-seeking activity, as shown by the incidence on meadowlarks given in table 3, is greatest and continues without interruption from July to the latter part of November. It is manifest only during warm periods in December, January and February. The threshold of larval host-seeking activity is apparently close to 70 degrees F. The high incidence on birds collected between January 20 and February 2 is explained by the fact that a warm spell in the preceding period extended over into the period in question.

The biweekly collection data for the period from March 16 to June 21 are tabulated in table 4.

The longevity of larvae varies from two to five months depending on the weather conditions. Under conditions conducive to desiccation, the length of life is materially shortened. Mortality is greatest during periods in which the top soil dries out.

The incidence of larvae on meadowlarks, as shown in table 3, indicates that the surviving larvae of the 1935 generation perished in the latter part of February or early in March 1936. This is supported by the disappearance of larvae from eggs deposited in an outdoor enclosure by two females that engorged the last week in September 1935, when the host-seeking activity of the adult had practically ceased. Hatching began the second week in November. The few larvae that persisted until March 1936, had perished by the latter part of the month.

Larvae from eggs that passed the winter and began hatching the first week in April 1936, were present in large numbers at the end of the third week. The number had decreased to relatively few by the end of the first week in May and only two were present the fourth week. The high mortality is attributed to a dry period that occurred during the latter part of April and early May as shown in figure 1.

Larvae from an egg mass that began hatching September 3, 1936, had decreased considerably in number by the second week in November. Only one larva survived until the first week in December. Mortality in this case is associated with an extended dry period. A corresponding decrease occurred, at the same time, in the larval incidence on meadowlarks (Table 3).

Larvae retained in cloth-covered tubes and bottomless fruit jars set in the soil lived much longer than those exposed to natural environmental changes in the outdoor enclosures. A few of the larvae that hatched from a mass of eggs during the first week in November 1935, lived in a jar until the latter part of April 1936.

The reduced host-seeking activity of larvae during cool periods, their longevity, and lack of resistance to desiccation are factors which may account in part for the limited distribution of this species.

Animals that have been found infested with Gulf coast tick larvae in southern Georgia include the meadowlark, *Sturnella magna;* bobwhite, *Colinus virginianus;* southern fox squirrel, *Sciurus niger niger;* eastern cotton rat, *Sigmodon hispidus hispidus;* towhee, *Popilo erythrophthalmus;* field sparrow, *Spizella pusilla pusilla;* southern gray squirrel, *Sciurus carolinensis carolinensis;* house wren, *Troglodytes aedon;* brown thrasher, *Toxostoma rufum;* kid; lamb; mockingbird, *Mimus polyglottos;* blue jay, *Cyanocitta cristata;* loggerhead shrike, *Lanius ludovicianus ludovicianus;* and the roof rat, *Rattus rattus alexandrinus.*

Birds are much more susceptible to larval infestations than mammals. In the laboratory, practically all larvae placed on the meadowlark, bobwhite and English house sparrow engorged, but only a few of those placed on the roof rat and cotton rat did so.

Natural larval infestations have not been observed to cause any deleterious effects on the host. A meadowlark carrying an infestation of 289 larvae of which about 200 were engorged, was apparently not affected. Under laboratory conditions, extreme emaciation was the only effect on meadowlarks that survived individual infestations from which between 2,400 and 3,400 larvae engorged.

Range habit is the most important factor determining the principal hosts among both birds and mammals. Any bird or mammal that visits grassland areas is likely to become infested, but only those habitually ranging such areas serve as important hosts.

The meadowlark is the principal host of the larval stage of the Gulf coast tick. It is the most abundant and the best adapted of the animals that serve as hosts of this stage in southern Georgia. It frequents open grassland and seeks food preferably in winter-burned and heavily grazed areas. Meadowlarks are gregarious in nature and search for food in scattered groups. They cover extensive areas in their early forenoon and late afternoon hunts. Their activities are ideal for the propagation of the larval stage. Of 113 meadowlarks collected between July 24 and November 20, the period of greatest larval activity, 79 were infested with a total of 2,030 larvae.

The bobwhite is next in importance as a host of the larval stage. It is terrestial in habit. In southern Georgia, its range extends well into open areas surrounding

swampy places which are usually the foci of its activity. Compared with the meadowlark as a host, the bobwhite is of lesser importance because it is less abundant, its range is less extensive, and it feeds in more or less compact groups. Of 17 specimens collected during the period of greatest larval activity, 15 were infested with a total of 169 larvae.

The fox squirrel is comparatively scarce; nevertheless, it is probably the most important host in the mammalian group. It roams in open grassland and covers extensive areas in its quest for food. Of 4 specimens collected during the period of greatest larval activity, 3 were infested with a total of 35 larvae.

The cotton rat is fairly abundant, but its importance as a host of the larval ticks is limited because of its localized activity. The range of this animal is confined to areas near its runs and burrows which are located under heavy vegetation along fence rows and near brush and fallen trees. Two specimens collected during the period of greatest larval activity, were infested with a total of nine larvae.

The towhee is a ground-inhabiting bird that is very active in underbrush and grassland areas that are thickly interspersed with palmettos and clumps of bushes. This species is comparatively scarce. Five specimens were collected during the period of greatest larval activity; three were infested with a total of eight larvae.

The field sparrow is quite numerous but it is limited in importance as a host, probably because of its small size and flitting activity. It ranges among grasses with clumps of bushes as its center of activity. Of 15 specimens collected during the period of greatest larval host-seeking activity, 3 were infested with a total of 16 larvae.

The gray squirrel is quite numerous, but seldom strays from arboreal areas. It visits outside the borders of such areas, occasionally making short runs across grassland. Of 14 specimens collected during the period of greatest larval activity, 5 were infested with a total of 10 larvae.

The house wren is comparatively scarce. It is active in low vegetation, particularly around the bases of trees and clumps of bushes. Only two specimens were collected; each one infested with two larvae.

The brown thrasher is also comparatively scarce. It confines its activity largely to thickets, with occasional visits in bordering grassland. Two specimens were collected during the period of greatest larval activity; one was infested with four larvae.

Other members of the host list are either rare during the season of larval activity or make only momentary visits in grassland areas.

Larvae attach almost exclusively on the head and neck of their hosts. Attachment occurs only on the head and neck of bird hosts; generally and around the ears and at the base of the head. On rodents, attachment is most frequent around the eyes. Larvae were found attached only on the face, near the muzzle, of young ruminants.

The time required for larvae to engorge ranges from 3½ to 7 days. In engorgement studies of moderate infestations on meadowlarks, 99 larvae engorged in 3½ days, 742 engorged in 4 days, 473 in 4½ days, 172 in 5 days, 46 in 5½ days, 8 in 6 days, 3 in 6½ days and 3 in 7 days. Engorgement occurred within the same range on the bobwhite, English house sparrow, cotton rat and the roof rat.

Both laboratory and field data indicate that detachment of engorged larvae occurs most frequently during the early part of the morning and in late afternoon when the host is active. The majority of nymph infestations in the field were single, which indicates that engorged larvae detach while the host is moving about. Of 95 meadowlarks collected with nymph infestations, 48 were infested with only 1 nymph, 16 with 2, 9 with 3, 9 with 4, 4 with 5, 3 with 6, 1 with 8, 1 with 9, 1 with 10, 1 with 11, 1 with 14 and 1 with 19. In moderate infestations on meadowlarks under laboratory conditions, 862 engorged larvae detached before mid-morning and 686 detached in the latter part of the day.

As soon as engorged larvae drop from the host, they begin crawling in the low vegetation and conceal themselves by wedging the body in natural crevices formed by parts of plants above the ground. Quiescent larvae are most frequently located between the sheath and stem of grasses. Under conditions which induce parasitic activity, engorged larvae become quiescent within two days. Lower temperatures prolong the prequiescent period. The quiescent larva is glued in

place by a wax-like body secretion which prevents it from being dislodged by wind or rain and also renders it quite resistant to desiccation.

Engorged larvae molt in from 9 to 12 days during periods in which the temperature ranges above 70 degrees F. When the temperature ranges below that, the time required is greatly prolonged. It is apparent that the threshold of development is not far below 70 degrees F. In incidence studies on meadowlarks, nymphal infestations occurred within two weeks following the first larval infestations which indicates that only a short time is required in July for the nymph to develop from the engorged larva. Engorged larvae, subjected to a constant temperature of 98 degrees F., require only 6 days to develop into nymphs. Those at room temperature molted in around 12 days.

From 50 engorged larvae placed in an outdoor enclosure October 21, 1935, 1 nymph was active January 15, 1936. From 200 that were similarly placed during the third and fourth weeks in November 1935, only 1 nymph was active by the second week in February 1936; several were active the first week in March and many the following week. From 80 engorged larvae placed in an enclosure March 11, 1936, 1 nymph was active April 9.

THE NYMPH.—In southern Georgia, nymphs are active in every month of the year as shown by the periodic incidence record in table 4. Activity and abundance are greatest, however, during late winter and spring when the daily maximum temperature averages above 70 degrees F. Nymphs that molt from engorged larvae during periods of relatively high temperatures remain inactive for only a short time, but those emerging during periods of moderate to low temperatures, particularly in the fall, remain inactive throughout such periods and even during intervening warm periods. One hundred newly emerged nymphs that were placed in an outdoor enclosure October 26, 1936, could not be stimulated to activity by natural means. They became active, however, on December 16, when the outdoor enclosure was subjected to the heat of an electric light. This observation indicates that nymphs emerging in the fall have a tendency to hibernate.

In general, the activity of the nymph is quite similar to that of the larva except that it is not of the same gregarious nature. The nymph remains concealed in vegetation until the approach of a host. In the vicinity of a host, it crawls actively about with a tendency to move in the general direction of the host and often makes temporary stops at terminal points

**Table 4.—Biweekly incidence of the Gulf coast tick nymph on meadowlarks in 1935–36.**

| Period of Collection | Birds | | Number of Nymphs | | | Maximum Daily Temp. Ave. °F. |
|---|---|---|---|---|---|---|
| | Number Examined | Percentage Infested | Average Per Infested Bird | Maximum Infestation | Per 100 Birds (Calculated) | |
| Oct. 14–27 | 3 | 0 | 0.0 | 0 | 0 | 80.4 |
| 28–Nov. 10 | 10 | 30 | 5.3 | 14 | 159 | 81.0 |
| Nov. 11–24 | 16 | 13 | 6.0 | 9 | 78 | 68.2 |
| 25–Dec. 8 | 26 | 15 | 1.3 | 2 | 20 | 63.7 |
| Dec. 9–22 | 10 | 10 | 2.0 | 2 | 20 | 54.7 |
| 23–Jan. 5 | 20 | 15 | 1.7 | 3 | 25 | 55.8 |
| Jan. 6–19 | 21 | 43 | 1.3 | 4 | 56 | 70.8 |
| 20–Feb. 2 | 25 | 52 | 3.3 | 10 | 172 | 61.9 |
| Feb. 3–16 | 4 | 50 | 1.0 | 1 | 50 | 55.6 |
| 17–Mar. 1 | 4 | 50 | 1.5 | 2 | 75 | 64.8 |
| Mar. 2–15 | 7 | 86 | 2.7 | 4 | 230 | 70.4 |
| Mar. 16–29 | 2 | 100 | 5.5 | 8 | 550 | 70.9 |
| 30–Apr. 12 | 18 | 78 | 2.8 | 11 | 218 | 73.5 |
| Apr. 13–26 | 11 | 73 | 2.3 | 5 | 168 | 76.9 |
| 27–May 10 | 5 | 80 | 2.5 | 5 | 200 | 84.6 |
| May 11–24 | 17 | 24 | 2.7 | 4 | 65 | 85.4 |
| 25–June 7 | 9 | 11 | 1.0 | 1 | 11 | 85.3 |
| June 8–21 | 10 | 10 | 1.0 | 1 | 10 | 87.6 |
| 22–July 5 | — | — | — | — | — | 91.7 |
| July 6–19 | 14 | 0 | 0.0 | 0 | 0 | 91.9 |
| 20–Aug. 2 | 13 | 23 | 1.3 | 2 | 30 | 91.2 |
| Aug. 3–16 | 11 | 18 | 3.5 | 6 | 63 | 88.6 |
| 17–Sept. 13 | — | — | — | — | — | 90.0+ |
| Sept. 14–27 | 8 | 25 | 2.0 | 3 | 50 | 90.7 |
| 28–Oct. 11 | 12 | 8 | 1.0 | 1 | 8 | 85.2 |
| Oct. 12–25 | 7 | 57 | 1.8 | 4 | 102 | 83.1 |
| 26–Nov. 8 | 20 | 15 | 1.0 | 1 | 15 | 77.1 |
| Nov. 9–22 | 17 | 0 | 0.0 | 0 | 0 | 68.4 |
| Nov. 23–30 | 7 | 0 | 0.0 | 0 | 0 | 59.0 |

on the vegetation in an effort to contact the host.

The longevity of the nymph varies from two to six months depending on the season of the year. Both humidity and temperature are determining factors. Those retained in cloth-covered containers set in the soil survived longer than those in outdoor enclosures. Nymphs that emerged the third week in August 1936, and were kept in favorable humidity at temperatures that ranged considerably above 80 degrees F. for the greater part of the time, began dying the third week in October. Of the original 50 only 3 persisted until December. Sixty nymphs from engorged larvae which molted the last week in November, 1935, were placed in an outdoor enclosure. The last representatives of this group died in late April 1936. Of 25 nymphs from engorged larvae that molted and were placed in a cloth-covered bottomless fruit jar the last week in November, 1935, 8 were active the second week in May 1936. These perished before the end of the following week.

One hundred nymphs from engorged larvae that molted the third week in March 1936, were placed in an outdoor enclosure. These had decreased considerably in number by the first week in May. Only 5 persisted until the second week in June and these perished before the end of the following week. Representatives from 20 nymphs that emerged the first week in March, 1936, persisted in a 16 millimeter cloth-covered tube until the first week in July.

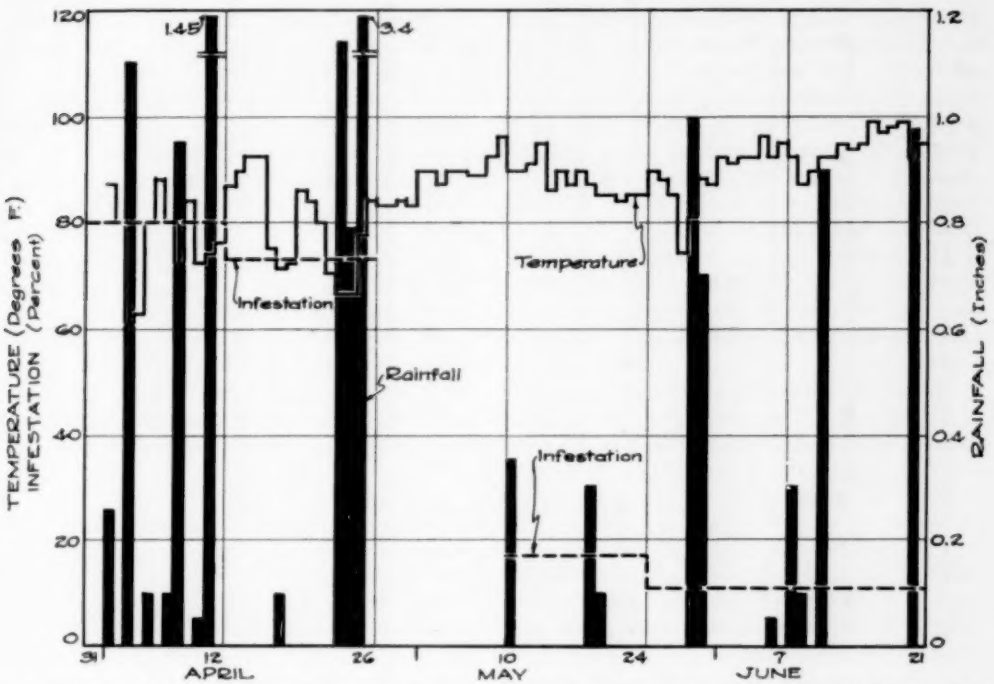


FIG. 1.—Rainfall, daily maximum temperature, and percentage of meadowlarks infested with the Gulf coast tick nymph in Berrien County, Georgia, 1936.

During the rainless period that extended from April 23 to May 12, the percentage of meadowlarks infested with nymphs in Berrien County, Georgia, dropped from 72 during the two weeks ending April 26, to 17 during the two weeks beginning May 11, as shown in figure 1. Of 5 birds collected April 17, 4 were infested with a total of 10 nymphs. Six birds were collected April 23; 4 were infested with a total of 10 nymphs. Six birds were collected in the same vicinity May 12, of which only 1 was infested. It carried 4 nymphs, all in the same state of engorgement.

The fact that the top soil in upland areas and in many low areas dried out during the period of low rainfall in the

middle and latter part of April and the first part of May, accounts for the decrease in incidence in the field and the high mortality among nymphs under observation in outdoor containers at the laboratory.

Animals that were found infested with the Gulf coast tick nymph in southern Georgia include the meadowlark, bobwhite, eastern cotton rat, southern fox squirrel, sheep, calf, towhee, house wren, American robin (*Turdus migratorius*), and the white-throated sparrow (*Zonotrichia albicollis*). The meadowlark and the bobwhite are the most important hosts. The cotton rat outranks the fox squirrel as a host of the nymph because of its greater abundance and of the dissemination of engorged larvae within its range by the principal hosts of the latter.

The nymph has no injurious effect on the host. In the laboratory, meadowlarks survived infestations ranging from 100 to 125 nymphs and suffered only extreme emaciation.

Nymphs attach on the head and neck of their hosts. The occipital region of the head is the most common place of attachment on birds. On mammals, attachment is likely to occur at any point on the head or neck.

The process of engorging is gradual until the nymph has increased to about half the replete dimension, after which completion requires a comparatively short time. Engorgement is usually completed during the night, while the host is inactive. In infestations of less than 30, nymphs engorge in 4½ to 7 days. In engorgement studies on meadowlarks under laboratory conditions, 19 nymphs engorged in 4½ days, 14 in 5 days, 37 in 5½ days, 18 in 6 days, 7 in 6½ days, and 2 in 7 days. The time required may be prolonged if the infestation is abnormally heavy or if the host is in poor condition.

Detachment of the engorged nymph occurs almost entirely during the morning, soon after the host becomes active. Of 1368 nymphs that engorged on meadowlarks under cage conditions, 1203 detached before mid-morning. Regardless of the time of day the host was infested, detachment began the morning of the fifth day.

After dropping from the host, engorged nymphs crawl about in the vegetation and wedge themselves in natural crevices formed by vegetative growth. They are usually found in the crowns of grasses where they become quiescent and molt. In the quiescent state, the nymph is very resistant to desiccation. At temperatures ranging between 70 and 80 degrees F., they molt in some twenty days. Higher temperatures decrease the time required and lower temperatures greatly prolong the period. Nymphs engorging in the fall and winter do not molt until spring.

Twenty engorged nymphs were placed in an outdoor enclosure in November 1935. One fully developed adult was found in the exuvia March 6, 1936. The earliest adult activity in this enclosure was noted April 30. In other outdoor studies, 6 engorged nymphs were placed in a 25 millimeter cloth-covered tube December 12, 1935. A male and a female emerged the week of March 31, 1936. Another male emerged the week of April 9. Three nymphs which engorged August 25, 1936, were placed in a cloth-covered tube under heavy vegetation. Adults emerged the week of September 12. At room temperature, 245 engorged nymphs that detached February 25, 1936, molted March 17 to 19.

ADULTS.—The season of host-seeking activity of the adult extends from mid-April to early October, but the greatest activity occurs from the latter part of June to the latter part of September. Activity is apparently governed to a great extent by temperature. The earliest record of parasitism by the adult was April 17. Although the adult is abundant during the spring, host-seeking activity remains at a minimum until summer as shown in figure 2. The majority remain inactive on the bases of plants near the soil. In 1935, infestations on sheep were heavy in the latter part of September, and very light in early October. There was no evidence of host-seeking activity in October 1936.

Laborabory and field data give evidence of a second generation. Field evidence of host-seeking activity of the second generation in September is shown in figure 2. Laboratory studies show that adults emerging in late summer, may either engorge or pass the winter.

The male precedes the female in host-seeking activity as shown by the incidence on sheep shown in table 5. By June 23, these sheep had become infested with 132

males and only 46 females. During the entire season, they were infested with a total of 385 males and 378 females. That

gorged nymphs which molted the last week in March, 1936, were placed in an outdoor enclosure. Only relatively few

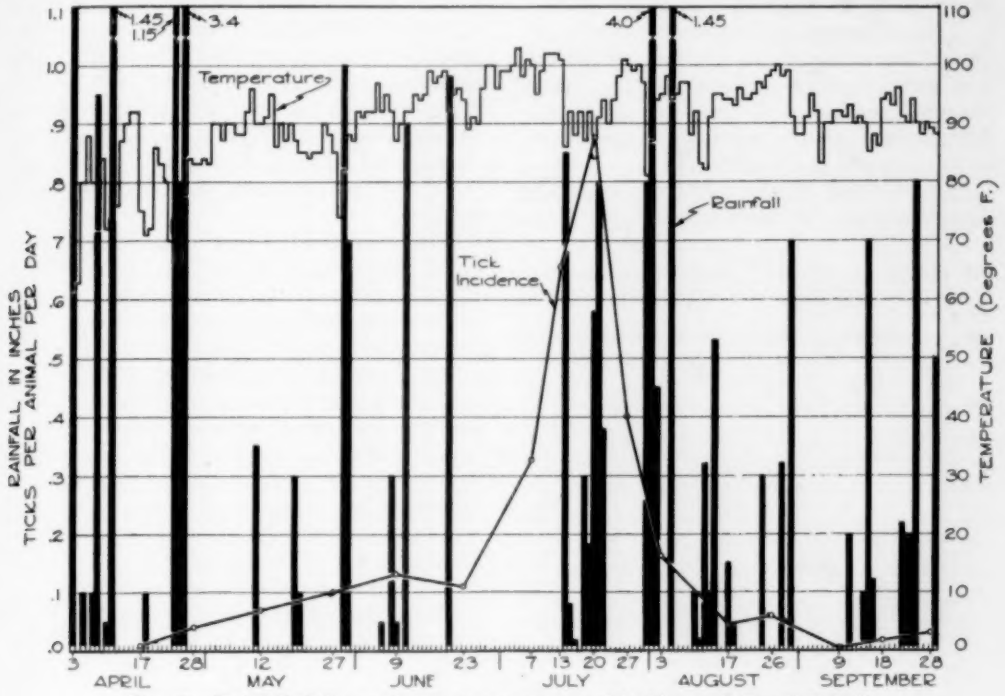


FIG. 2.—Rainfall, daily maximum temperature, and incidence of the adult Gulf coast tick on sheep in Berrien County, Georgia, 1936.

there is no significant difference in the sex ratio was also proved in adult emergence. From one group of engorged nymphs, 409 males and 460 females emerged.

The longevity of adults emerging in the spring varies from seven to eight months under normal conditions, but individuals passing the winter live for a longer time. The incidence studies on sheep (figure 2) show that the longevity of the adult in the field may be materially shortened by adverse weather conditions. Adults are quite resistant to desiccation during the early part of their existence. The majority survived the rainless period from June 21 to July 13, 1936, but the incidence fell sharply during the dry spell in late July and remained low during the remainder of the season. A similar mortality occurred in ticks used in longevity studies at the laboratory during these periods. The susceptibility of adults to desiccation is probably the most important factor restricting the distribution of the Gulf coast tick.

Fifty males and 50 females from engorged nymphs survived until the first week in August and all had perished except one male by the third week. It disappeared the first week in October. Representatives from adults that emerged in March and were kept under favorable conditions, showed very little mortality previous to October,

**Table 5.—Periodic incidence of the adult Gulf coast tick on regularly examined sheep in Berrien County, Georgia, 1936.**

| Date of Examination | Number Animals Examined | Ticks Per Animal Per Day* | Number of Ticks | |
|---|---|---|---|---|
| | | | Males | Females |
| April 17 | 25 | .008 | 3 | 0 |
| April 28 | 25 | .036 | 8 | 2 |
| May 12 | 25 | .069 | 17 | 7 |
| May 27 | 25 | .107 | 31 | 9 |
| June 9 | 31 | .134 | 39 | 15 |
| June 23 | 30 | .112 | 34 | 13 |
| July 7 | 30 | .326 | 62 | 75 |
| July 13 | 30 | .655 | 47 | 71 |
| July 20 | 28 | .872 | 72 | 99 |
| July 27 | 28 | .403 | 39 | 40 |
| Aug. 3 | 28 | .163 | 9 | 23 |
| Aug. 17 | 28 | .051 | 9 | 11 |
| Aug. 26 | 27 | .062 | 10 | 5 |
| Sept. 9 | 26 | .005 | 1 | 1 |
| Sept. 18 | 25 | .018 | 0 | 4 |
| Sept. 28 | 23 | .030 | 4 | 3 |

* Average number of ticks accumulated per animal per day during the interval between each examination.

but only a small percentage persisted until December. A female which emerged the third week in December 1935, was still alive the third week in December 1936.

The following animals were found infested with the adult Gulf coast tick in southern Georgia: Sheep, swine, goat, domestic cattle, dog, gray fox and mule. Sheep and swine were apparently the most suceptible to infestations.

Attachment of the adult on ungulates occurs almost exclusively inside the pinna

**Table 6.—Individual engorgement record of the female Gulf coast tick, with delayed copulation.**

| Date Attached | Date of Copulation | Detachment | | |
|---|---|---|---|---|
| | | Date of | Days After Copulation | Days After Attachment |
| July 23 | July 29 | Aug. 2 | 4 | 10 |
| July 25 | July 29 | Aug. 4 | 6 | 12 |
| Aug. 1 | Aug. 7 | Aug. 11 | 4 | 10 |
| Aug. 1 | Aug. 7 | Aug. 11 | 4 | 10 |
| Aug. 1 | Aug. 7 | Aug. 13 | 6 | 12 |
| Aug. 11 | Aug. 26 | Aug. 31 | 5 | 20 |
| Aug. 23 | Aug. 26 | Aug. 31 | 5 | 8 |
| Sept. 1 | Sept. 7 | Sept. 11 | 4 | 10 |
| Sept. 3 | Sept. 16 | Sept. 20 | 4 | 17 |
| Sept. 3 | Sept. 16 | Sept. 20 | 4 | 17 |
| Sept. 5 | Sept. 18 | Sept. 23 | 5 | 18 |
| Sept. 5 | Sept. 21 | Sept. 26 | 5 | 21 |
| Sept. 19 | Sept. 25 | Sept. 30 | 5 | 11 |
| Sept. 19 | Sept. 25 | Sept. 30 | 5 | 11 |
| Sept. 23 | Sept. 29 | Oct. 2 | 3 | 9 |
| Sept. 23 | Sept. 29 | Oct. 2 | 3 | 9 |

of the ear. However, it is not uncommon to find infestations on the outside of the ear and to a lesser extent on the neck, at the base of the horn and occasionally at other points. There is a tendency to attach in creases and adjacent to abnormal growths or to ticks already attached. Because of this latter habit, it is usually found in groups.

The natural tendency of ungulates to swing the ear to and fro when stimulated by movement on the hair in the ear, is the dominant factor inducing the adult to attach. The ear-reflex causes the adult to cease crawling and cling to the hair. Repetition of the animal's effort to disengage the simulating factor causes the tick to insure its position by going deeper among the hairs. In this position, the tendency to crawl ceases and attachment follows. Although host behavior is dominant, other factors encourage attachment.

Sheep with deformed ears, or growths in the ears, are more susceptible to infestations than animals with normal ears. Animals so affected are seldom without infestations during the season of host-seeking activity. One sheep examined July 29, 1936, for the first time that season, was infested with 221 adults, most of which were males. Animals free of infestations or deformities often offer considerable resistance to ticks by disengaging them with the hoof before they become firmly attached. Only a very small percentage of sheep, however, are able to ward off infestations during an entire season.

The male tick must remain attached six or seven days before it can be induced to copulate. Although copulation can seldom be induced during the sixth day, the majority will copulate before the end of the seventh day. The male remains attached in one place throughout the precopulation period. Sexually mature males are stimulated to activity by other ticks crawling over them. If the male is not disturbed, it may remain attached for several weeks even when females are attached in the same ear. When stimulated, sexually mature males detach and seek attached or free, fertile or infertile females with which they copulate. However, if the male is disturbed before taking the position for copulation, it immediately reattaches. The copulating position is held from ten to fifteen minutes and a spermatophore is left protruding from the genital aperture of the female. The male usually reattaches in the same position with respect to the female as that held during copulation.

The number of females that a male is able to fertilize is apparently not limited. One male induced the engorgement of six females within a period of five days. Males remain on the host for an indefinite period. One male tick on one sheep and three on another remained attached from September 24 to December 22, a period of 89 days.

Copulation is essential to normal engorgement. Females become replete in 4 to 8 days following copulation. Those that have been attached two days or more before copulation require 4 to 6 additional days to engorge, as shown by the data in table 6. Those that copulate on the day of attachment require 6 to 8 days, as shown by the data in table 7. The process of actual engorgement requires from $3\frac{1}{2}$ to $5\frac{1}{2}$ days. Engorgement is gradual up to the intermediate stage after which ticks

**Table 7.—Individual engorgement record of the female Gulf coast tick on sheep infested with sexually mature males.**

| Date Attached | Detachment | |
|---|---|---|
| | Date of | Days After Attachment |
| Aug. 27 | Sept. 3 | 7 |
| Aug. 27 | Sept. 3 | 7 |
| Aug. 27 | Sept. 3 | 7 |
| Aug. 29 | Sept. 4 | 6 |
| Aug. 29 | Sept. 6 | 8 |
| Sept. 1 | Sept. 7 | 6 |
| Sept. 1 | Sept. 8 | 7 |
| Sept. 3 | Sept. 9 | 6 |
| Sept. 3 | Sept. 10 | 7 |
| Sept. 5 | Sept. 11 | 6 |
| Sept. 5 | Sept. 12 | 7 |
| Sept. 5 | Sept. 13 | 8 |
| Sept. 8 | Sept. 14 | 6 |
| Sept. 8 | Sept. 15 | 7 |
| Sept. 8 | Sept. 16 | 8 |
| Sept 8 | Sept. 16 | 8 |
| Sept. 10 | Sept. 18 | 8 |
| Sept. 14 | Sept. 21 | 7 |
| Sept. 14 | Sept. 22 | 8 |
| Sept. 15 | Sept. 23 | 8 |
| Sept. 23 | Oct. 1 | 8 |
| Sept. 25 | Oct. 3 | 8 |

usually become replete and detach in less than a day. In the absence of the male, engorgement is indefinitely prolonged. However, a gradual enlargement may occur up to varying stages, but such forms always have an abnormal appearance. One infertile female remained attached from the latter part of October 1935, until early January 1936, a period of approximately 70 days.

The engorging female causes swelling and the host becomes very sensitive at the point of attachment. Heavy infestations throughout the season may stunt young animals and keep others in such poor condition that many, particularly sheep, are unable to survive the period when food is scarce on the range. More important is the fact that infestations may cause conditions that induce screwworm attack. Screwworm infestations resulted in two of three healthy sheep because of effects produced by approximately 15 adult ticks in the ear. In two of the animals, screwworm flies deposited their eggs on a gray jelly-like exudate that developed among the engorging ticks. The infested ear of the other animal remained clean and screwworm eggs were not deposited.—11-16-1938.

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# General Information Concerning the Oriental Fruit Moth in Japan and Chosen

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In conjunction with a survey concerning the parasites of the oriental fruit moth, *Grapholitha molesta* (Busck), in Japan and Chosen, conducted during 1932 and 1933, considerable information concerning the host insect in those countries was acquired from field observations, from contacts with native entomologists and fruit growers, and from published records.*

* The writer is indebted to Noboru Suyetake for his valuable assistance as interpreter in making the various contacts and for his translations of references published in Japanese.

DISTRIBUTION.—As has been pointed out by Harukawa (1925), damage caused by the oriental fruit moth was first noticed in Okayama Prefecture in Japan in 1901 and 1902, and the insect is known to have been present in Chosen at least since 1915 or 1916. It is now generally distributed throughout the central and southern parts of Japan. It has been reported, or is known to occur, in all prefectures of Honshu, with the possible exceptions of Aichi and Mie, for which no records are available, and in all prefectures of Shikoku and Kyushu. No record was found to indicate that it occurs on the island of Hokkaido. Muramatsu (1927) has reported it from all the prefectures of Chosen.

HOST PLANTS AND INJURY.—Harukawa (1923) and Muramatsu (1927) list the following as the known host plants of *Grapholitha molesta* in Japan and Chosen: Both fruit and twigs of peach, sand pear, pear, quince, apple, apricot, black plum (*Pirus triflora*), and Chinese malus (*Cormus tschonoskii*), and the twigs only of cherry, Japanese flowering cherry, sand cherry, Japanese apricot (*Prunus ume*), and plum.

It is chiefly the twigs of peach that are severely attacked and, although the fruit is sometimes rather heavily infested late in the season, in general the damage to peach fruit does not appear to be considered as serious in Japan and Chosen as it is in the United States. Harukawa (1923, 1925), in experiments conducted in Okayama Prefecture, found that adults of the overwintering generation and of the first and second summer generations oviposit chiefly on the foliage of peach trees, although some eggs are laid by the moths of these broods on other host plants, including the foliage and occasionally the small green fruit of the pear. He found that the percentage of eggs deposited on pear trees by moths of these early generations increased gradually as the season advanced, that moths of the third generation laid a still greater proportion of eggs on pear, and that more than 75 per cent of the eggs produced by moths of the fourth generation were deposited on pear trees. He further found that the number of eggs laid on pear fruit began to increase from about the middle of July and showed a marked increase about the middle of August. From the results of his experiments and observations, Harakuwa concluded that oriental fruit moth adults oviposit on peach foliage in preference to that of the pear and that, therefore, when both peach and pear orchards are situated in the same locality, as is frequently the case in Japan and Chosen, there is a tendency for moths of the overwintered and early summer generations to migrate to the peach orchards. He further concluded that after about the middle of July the moths tend to migrate to the pear orchards, perhaps being attracted by the odor of the ripening fruit and because of the scarcity of suitable growing twigs on peach trees at that time of the year. This possible seasonal choice of host plants, together with the fact that a large portion of the peach fruit produced in Japan and Chosen is protected by bagging during the growing period, may account, in part at least, for the apparently less extensive damage to peaches caused by the oriental fruit moth in those countries as compared to that in the United States.

*Grapholitha molesta* is of primary importance in Japan and Chosen as a pest of the sand pear, which is of considerably more importance as a fruit crop in both countries than is the peach. Harukawa (1923) reports that in the vicinity of Kurashiki, Okayama, larvae of the oriental fruit moth begin to enter pear fruit about the middle of July, and he records injury up to as high as 45.9 per cent, the injury being most severe during September and October.

Injury by the oriental fruit moth to apple fruit occurs in some sections of Japan, and in the quince producing region near Lake Suwa, Nagano, it was learned that early and careful bagging of the quince fruit is necessary in order to prevent almost 100 per cent infestation of this crop.

The injury to fruit caused by the larvae of *Carposina sasakii* Mats., a frequent pest of peach, pear, apple, quince, and plum in Japan and Chosen, is, according to some authorities, frequently confused with that caused by *Grapholitha molesta*. The adults of the two species are readily distinguishable, and Harukawa (1925) has pointed out that the larvae can best be distinguished by the lack of the anal fork in the former species and its presence on larvae of the latter species.

LIFE HISTORY AND HABITS.—In 1932,

17.9 per cent of the hibernating larvae of the oriental fruit moth within cocoons found on sand pear trees at Ninomiya, Kanagawa, on February 20 had pupated, and in 1933, 15.1 per cent and 28.9 per cent of those found at the same locality on March 9 and 14, respectively, had pupated. At Inaginaganuma, Tokyo, 16.7 per cent of those found on February 24, 1932, were pupae. In Nagano Prefecture in 1932, 30.8 per cent of the insects collected from apple trees near Nagano City on March 23 and 25.1 per cent of those found in quince orchards at Kamisuwa on March 25 were pupae. By April 1 more than 90 per cent of the larvae at the latter locality had pupated, and an oriental fruit moth adult was captured in a quince orchard there on April 7.

Several thousand hibernating fruit moth larvae in cocoons confined in a series of spherical wire cages were kept outdoors at Yokohama during the winter of 1932–33. Some of the cages were placed where they would obtain the maximum exposure to direct sunlight and the others were placed on the shaded side of a building and received no direct sunlight. Moths began to emerge in the cages on March 22, 1933, and emergence was completed on May 24. The daily emergence in the cages exposed to sunlight was greatest during the period April 3 to 19, and in those kept in the shade the daily emergence was greatest during the period May 1 to 8. Harukawa (1923, 1925) reported that in the vicinity of Kurashiki the transformation to the pupal stage begins about the end of March, adults begin to emerge usually early in April, depending upon the season, and maximum emergence usually occurs towards the end of April.

In 1932 daily scouting indicated that fruit moth larvae first began to enter peach twigs in Kanagawa Prefecture on May 13. In 1933 unhatched eggs were found on the foliage of peach trees at several localities in Kanagawa and Tokyo Prefectures on May 9 and larvae began to enter twigs on May 11. In 1932 infested twigs were not found in large numbers in these and neighboring prefectures until May 23.

Harukawa (1923, 1925) found that in Okayama Prefecture there are five generations of the fruit moth, or occasionally four generations with a partial fifth, and reports that other workers have recorded four generations in the prefectures of Gumma, Niigata, and Shimane. The dates on which moths of the various generations began to emerge at Kurashiki in 1918 and 1919, according to Harukawa's observations, conform very closely to the dates of similar emergence recorded by Peterson and Haeussler (1926) at Riverton, N. J., in 1925, as is indicated in table 1. Five generations of the oriental fruit moth occurred at the two localities in the years compared.

**Table 1.—Comparison of first emergence dates of oriental fruit moth adults of each generation at Kurashiki, Japan, and at Riverton, N. J.**

| | Date First Adults Emerged | | |
|---|---|---|---|
| | Kurashiki, Japan | | Riverton, N. J. |
| Generation | 1918 | 1919 | 1925 |
| Overwintering | April 27 | April 20 | April 13 |
| First | June 10 | June 5 | June 5 |
| Second | July 7 | July 10 | July 8 |
| Third | Aug. 3 | Aug. 8 | Aug. 9 |
| Fourth | Sept. 5 | Sept. 6 | Sept. 7 |
| Fifth | (Overwintered) | (Overwintered) | (Overwintered) |

On peach the eggs are usually deposited on the under side of the foliage. In pear orchards the eggs may be found on the foliage, on the fruit, and sometimes on the paper covering that is used to protect the growing fruit. According to Harukawa (1923), adults sometimes oviposit on young green pear fruit. He also indicates that on ripe pear fruit the eggs may be found on the side of the fruit, on the fruit stem, and especially in the stem and calyx cavities.

In general the oriental fruit moth in Japan and Chosen appears to differ very little in its life history and habits from the insect as it has adapted itself to conditions in the United States.

Control Measures in Japan and Chosen.—Individual orchardists were occasionally encountered in various sections of Japan who follow the practice of periodically clipping the twigs infested by larvae of the oriental fruit moth from their peach trees. Such twigs are burned or otherwise disposed of to destroy the contained larvae. It is doubtful whether this practice is of much value, owing to the probability of migration of moths emerging in other nearby peach orchards which do not receive the same care and from

pear orchards located in the immediate vicinity.

In the extensive quince-growing region near Lake Suwa, Nagano, the destruction of hibernating larvae by scraping the bark from the quince trees during the winter is commonly practiced. This undoubtedly aids considerably in reducing the large overwintering population of fruit moth larvae that form cocoons on the trunks and larger branches of the quince trees.

The bagging of peach, pear, quince, and other fruits, commonly practiced

FIG. 1.—Types of bags commonly used for covering fruit in Japan.

throughout Japan and Chosen, is probably the most effective measure in reducing infestation of the fruit. This practice is followed not only because of this one pest but also as protection against other fruit pests such as *Carposina sasakii* and *Nephoteryx pirivorella* Mats. Although no definite records of the degree of protection afforded by bagging of the fruit were obtained, the general opinion among entomologists and growers seems to be that the protection obtained justifies the cost and extra labor required in bagging the fruit. According to Muramatsu (1927), the use of bags appears to be preferable to the use of insecticides for some fruit for the reason that the bags afford protection right up to picking time, whereas insecticides do not give so good protection no matter how well or how often applied. Weather affects insecticides more than it does the bags, and the use of bags is more economical where the injury is severe.

The fruit crop must be covered as early as possible if the maximum protection is to be obtained. In Kanagawa Prefecture in 1932, bagging of peaches was begun shortly after the middle of May, when the peaches averaged less than 1 inch in diameter. The writer was informed that in the quince region near Lake Suwa the quince fruit is usually bagged during the latter part of May or about 10 days after blossom fall. When peaches and pears are bagged, the fruit is thinned immediately before the bags are applied and, as far as is possible, fruit which may already have become infested is culled at that time. A second bag is sometimes placed over pear fruit later in the season as additional protection against burning from the rays of the sun, and much of the quince fruit in Nagano Prefecture is covered by double bags as additional protection against attack by larvae of the oriental fruit moth.

The bags used are made of several kinds of paper material. Old newspapers appear to be most commonly used, owing to availability and comparatively low cost of this material. Waxed paper, brown wrapping paper, mulberry paper, parchment paper, and paraffined paper are among other types used. The bags are often waterproofed or otherwise treated by coating with some material to make them more durable. Muramatsu (1927) records persimmon juice, paulownia oil, perilla oil, and poisons as materials used for this purpose, and states that persimmon juice is most commonly used because of its cheapness, although it has less effect than oils in increasing durability. Newspaper bags do not last so long as some others and are frequently used on peaches because of the relatively short season of this crop. Bags made of more durable material are usually employed for pear, and on quince the inner bags are sometimes of waxed paper and the outer bags of newspaper. Some orchardists use bags that are entirely closed at the bottom, while others leave the bottom of the bags open, clip the two lower corners, or punch holes in the bottom of the bags. The purpose of this is to allow ventilation and prevent the fruit from sweating. Muramatsu reports that triangular shaped bags were once used on a large scale in Chosen, but that bags of this shape were gradually given up, as strong winds cause them to twist the fuit stems and, moreover, they are rather easily damaged by rain. Bags observed by the writer in common use throughout Japan were square or slightly oblong (fig. 1). Many growers make their own bags during the winter, and estimates obtained in Kanagawa Prefecture indicate that costs of materials and preparation of the bags range from about 2 to 5½ yen per 10,000 bags, depending upon

the material used and whether or not the paper is waterproofed or otherwise treated. One yen is equivalent to approximately 30 cents.

The bags are attached by slipping the open mouth over the fruit and tying firmly about the fruit stem. Reed grass is commonly used to tie the bags and some growers use short lengths of fine wire for this purpose. One grower, who employed chiefly women and boys for this work, claimed that the best workers could bag more than 2,000 peaches a day and that the labor for bagging averaged about 50 sen a day plus one meal for each worker. Other estimates obtained indicated that experienced workers averaged about 1,000 bags a day. From a few to several hundred bags are placed on each tree, depending upon the size of the crop. When the fruit is picked, the torn bags are frequently left on the trees and are removed during the dormant season as the trees are pruned.—10-9-39.

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# Toxicity of Phosphorus to Cockroaches*

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Phosphorus dispersed in a viscous medium (phosphorus paste) has been used successfully for many years by pest control operators for the control of rodents and certain species of cockroaches and has recently been recommended by Back (1937) who writes as follows: "Phosphorus pastes . . . are excellent for the control of roaches, particularly the larger species . . . " However, nothing is yet known about the toxicology of phosphorus with respect to insects. In this paper information is given on the relative toxicity of phosphorus, sodium arsenite and sodium fluoride as stomach poisons for the American cockroach, *Periplaneta americana* (L.); on the relative susceptibility of the American cockroach and the German cockroach, *Blattella germanica* (L.) to phosphorus as a stomach poison; and on the effect of phosphorus on the American cockroach by injection, by contact and by exposure to the vapors of phosphorus and its oxides in small closed containers.

MATERIALS AND INSECTS.—The phosphorus used in all work here reported consisted of fine particles dispersed in a viscous medium of undisclosed composition; in other words, a commercial phosphorus paste.

The following report was made by the St. Louis Testing Laboratory, Inc. on a sample of this paste purchased in the open market.

"On microscopic examination we found the diameter of the particles ranging from 2.5 to 10 microns down to colloidal or submicroscopic sizes for the smallest particles."

Referring to alleged fire hazard in the use of this paste the same laboratory reported as follows:

"In such a fine state of subdivision surrounded by 98 per cent non-inflammable material, these particles of yellow phosphorus cannot produce sufficient heat to start combustion. We confirmed this statement by heating the paste on kerosene saturated filter paper to 250 degrees F., and also by rubbing the paste spread on glass with a gasoline saturated piece of waste. It is our opinion that this material cannot be considered a fire hazard."

A subsample of the paste used in the present experiments was analyzed by the laboratory just mentioned and by H. C. Cheng of this university. Almost identical

* The first part of this work on relative toxicity was sponsored by the Sennewald Drug Company, St. Louis, Missouri, through the Research Foundation of The Ohio State University. *Senco* Phosphorus Paste was used throughout the investigation. The term "phosphorus" in this paper is to be understood to mean "yellow phosphorus."

results were obtained for phosphorus content—practically 2.00 per cent.

The sodium arsenite used in our tests was a white powder, found by H. C. Cheng to contain 76.0 per cent $As_2O_3$. The sodium fluoride was a C. P. white powder.

The two species of cockroaches used in this work were taken from the stock cages described by Woodbury and Barnhart (1939). In most cases only nymphs approaching maturity were selected for the tests.

THE RELATIVE TOXICITY OF PHOSPHORUS, SODIUM ARSENITE AND SODIUM FLUORIDE AS STOMACH POISONS FOR THE AMERICAN COCKROACH.—The primary purpose of this work was to find the median lethal dose (M.L.D.) of finely divided phosphorus in diluted paste for large nymphs of the American cockroach. In order better to appreciate the degree of toxicity of phosphorus, attempts were made to determine the M.L.D. of sodium arsenite in terms of $As_2O_3$, and of sodium fluoride in the same medium for purposes of comparison.

In order to feed predetermined doses of finely divided phosphorus to the American cockroach, it was desirable to place upon the mouthparts a measured volume of an attractive, viscous liquid carrying the phosphorus in uniform suspension. To measure the dosages it was necessary to dilute the commercial phosphorus paste. Syrup containing 75 per cent cane sugar syrup and 25 per cent maple syrup proved to be a satisfactory diluent, for paste so diluted and placed upon the mouthparts was accepted readily by the insects. It was not possible to use a glass capillary pipette to measure and apply such a viscous liquid, but satisfactory results were obtained with a Luer tuberculin syringe having the usual fine needle replaced by a metal tube of larger bore. In general, dosage of phosphorus was adjusted by altering concentration rather than volume and in most cases the concentration was adjusted so that the volume to be fed was 0.01 for each insect.

In conducting a series of feedings, the selected insects were weighed and weighed quantities of the paste were diluted to obtain concentrations calculated to give to each insect the desired dose of phosphorus when 0.01 cc. was placed upon its mouthparts. The dose was administered simply by holding the nymph between the thumb and first finger of the left hand and gradually ejecting the dose from the syringe upon the mouth-parts with the other hand. The orifice of the delivery tube was held close to the mouth-parts until the dose had been taken, usually in less than 3 minutes. Diluted paste containing phosphorus and the same liquid without phosphorus were taken with equal rapidity. Few insects were seen to regurgitate after taking their doses. After each insect was fed it was placed by itself with food (a mixture of ground whole wheat, dried skim milk and yeast, McCay and Melampy (1937)) in a half-pint cardboard container having a perforated celluloid top and an automatic watering tube in the bottom (Woodbury 1938). Here the insects, including some checks that had received no syrup, were held for daily observations. Unaffected insects were discarded at the end of 3 weeks; affected insects were held until they died or (rarely) recovered.

Dated observations were recorded on mortality and on the activity of treated insects as compared with the normal checks. The temperature of the room in which the insects were kept was fairly constant, ranging between 76 and 83 degrees F.

Before the M.L.D. of phosphorus could be determined, it was necessary to make preliminary experiments with a wide range of doses (0.007 to 0.32 mg. of phosphorus per gm. of body weight) to become familiar with the behavior of poisoned insects, to find the period of their survival and to estimate the range of doses in which the M.L.D. might be expected to lie. It was found that a few nymphs survived the lowest doses but that most of them died, the survival period being related to the dose. Lethal doses of phosphorus, regardless of quantity, did not increase the normal activity of the insects but retarded their activity, causing them to become sluggish and unresponsive to stimuli until death ensued. At high dosages death sometimes occurred within 24 hours, at low dosages, near the M.L.D., insects sometimes lingered a month or more before death occurred. Insects that were obviously affected by phosphorus rarely recovered. The death of nymphs following a long survival period may be due partly to their inability to eat and drink. However, untreated check insects

lived longer than a month without food or water. Check insects that received large doses of unpoisoned syrup followed by the normal diet and those that received the normal diet only were alive, and behaving normally (with a very few exceptions) in the small observation cages, at the close of the observation period. The effect of phosphorus was therefore clear cut—insidious and slow but sure in its lethal action.

As the preliminary experiments indicated that the M.L.D. lay between 0.01 and 0.035 mg. per gm., a more intensive study was made of the effect of doses within this range. The doses fed, the numbers of insects receiving each dose and their mortality in per cent are shown in figure 1. The dose required to kill 50 per cent of the insects (the M.L.D.) was found to be close to 0.020 mg. per gm. as shown in figures 1 and 2. The mean survival time of the insects that died in these tests ranged from 55 days (1 insect) at 0.01 mg. per gm. to 9.7 days at 0.35 mg. per gm.

A more precise determination of the M.L.D. could have been carried out, including an estimate of reliability (Bliss, 1938), but the labor involved did not seem to be warranted for present purposes.

Sodium arsenite and sodium fluoride, dissolved in the same viscous medium in which suspended phosphorus was administered, were fed quantitatively to large nymphs of the American cockroach.

Doses of sodium arsenite ranging from 0.011 to 0.958 mg. of $As_2O_3$ per gm. of body weight were fed to 36 nymphs. These doses were not taken so rapidly as were those of phosphorus. Only 10 nymphs died and the distribution of doses apparently causing death was so wide and irregular that the region of the M.L.D. was not clearly defined. However, as some nymphs were unaffected by doses as high as 0.77 mg. per gm., it appeared that sodium arsenite in syrup had little toxicity. This unexpected result might be due to unobserved regurgitation or to some protective effect of the sugar in the solvent. It is known that sugar increases the acidity in the crop of cockroaches (Wigglesworth 1927). This may in some way reduce the toxicity of the arsenical. To get some information on this point, sodium arsenite dissolved in distilled water was fed to 29 large nymphs. The aqueous solution was not taken readily and regurgitation was often observed. However, it was clear that sodium arsenite in water was more toxic than in syrup, though its toxicity was still inferior to that of phosphorus. The M.L.D. in water in terms of $As_2O_3$ probably lay between 0.04 and 0.2 mg. per gm. No attempt was made to delimit it.

It was still more difficult to feed sodium fluoride in diluted paste to the insects, but by persistance 43 nymphs were fed doses ranging from 0.12 to 0.55 mg. per gm. Only three of these insects were killed. The toxicity of sodium fluoride in diluted paste was much lower than that of phosphorus, but the M.L.D. was not determined.

Bringing together the results on relative toxicity, we find that phosphorus in diluted paste has no deterrent effect on feeding and is much more toxic than sodium arsenite and sodium fluoride in the same medium. The low M.L.D. of phosphorus, 0.02 mg. per gm., shows that it is highly toxic to nymphs of the American cockroach.

THE RELATIVE SUSCEPTIBILITY OF THE GERMAN COCKROACH AND THE AMERICAN COCKROACH TO PHOSPHORUS AS A STOMACH POISON.—Phosphorus paste is believed by pest control operators to be ineffective against the German cockroach. The label on the product used in this investigation stated that "this product is not effective against the small brown roach [German cockroach] found in kitchens and pantries." It was therefore of interest to find out whether its alleged ineffectiveness should be attributed to low toxicity or to lack of attractiveness or to both factors.

Large nymphs of the German cockroach selected for feeding tests ranged in weight from 0.038 to 0.085 gm.; mean 0.059 gm., or about a fourteenth of the weight of the American cockroach nymphs. These small nymphs could not be held between the fingers for feeding and were therefore supported by inserting the head through a hole in rubber dental dam stretched over a pill box. The phosphorus paste diluted with syrup was then applied to the mouth-parts in the manner described for the American cockroach. Although the German nymphs were much smaller than the American, the same volume of diluted paste, 0.01 cc., had to be fed to them in order to measure it

accurately. One would expect this volume to be taken more slowly by the German roaches than by the American, but the rate of imbibition of the phosphorus paste by the former seemed much slower than could be accounted for by their smaller size, which suggested that it might not be an attractive food.

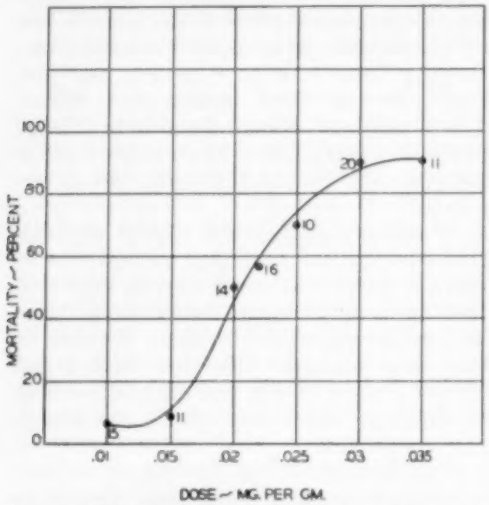


FIG. 1.—Relation between dose of phosphorus and mortality of large nymphs of the American cockroach.

Preliminary tests to locate the region of the M.L.D. were followed by the feeding of doses ranging from 0.1 to 0.35 mg. per gm. The number of insects fed each dose and the per cent mortality observed are shown in figure 2, in which the results previously obtained with the American cockroach (Fig. 1) are also shown. To make comparison easier, a logarithmic scale is used against probits. It is seen that the M.L.D. of phosphorus for the German cockroach is about 0.13 mg. per gm., 6.5 times greater than the M.L.D. for the American cockroach. It is therefore concluded that the German cockroach is less susceptible to phosphorus than is the American cockroach and may also be less likely to eat it. Thus we have some explanation for the failure of phosphorus paste to control the German cockroach in practice.

The German cockroaches did not survive lethal doses of phosphorus as long as did the American species, nor did check insects without food and water live so long. The mean survival time of insects that died in the tests for determination of M.L.D. ranged from 7.4 days at 0.15 mg. per gm. to 3.7 days at 0.35 mg. per gm.

THE EFFECT OF PHOSPHORUS ON THE AMERICAN COCKROACH WHEN ADMINISTERED BY INJECTION, BY CONTACT AND BY EXPOSURE TO FUMES.—Having proved that finely divided phosphorus is a highly toxic stomach poison for the American cockroach, it was of interest to know whether it would kill the insects when administered in other ways.

A Luer tuberculin syringe with hypodermic needle was used to inject suspensions of phosphorus into large nymphs. The needle was inserted between midabdominal segments on the right side of the venter and was thrust cephalad under the cuticle. Insects that bled freely were discarded.

Syrup could not be used as the diluent for the phosphorus paste because the injection of syrup alone killed the insects. Diluted Levy's physiological salt solution (Yeager 1935, p. 10) was therefore used as the diluent. When injected alone it had no effect upon the insects, but on the other hand the particles of phosphorus settled out more rapidly in this less viscous medium and as the phosphorus was not uniformly dispersed at the time of injection, it is doubtful that the volume injected (0.02 cc.) was a precise measure of the quantity of phosphorus that entered the body cavity. At any rate the particles of phosphorus did not flocculate in the salt solution, and an effort was made to keep them in uniform suspension by rotating the syringe between injections.

Doses of phosphorus calculated to range between 0.006 and 0.379 mg. per gm. were injected into 58 insects. A smaller number were injected with the same liquid without phosphorus. Following injection they were held for observation in the manner already described. The M.L.D. of phosphorus by injection appeared to lie between 0.04 and 0.08 mg. per gm.

One would expect a water-soluble poison to be more toxic by injection than by mouth (Campbell 1926), but the same relation may not hold in the case of a water-insoluble substance like phosphorus. The results just mentioned suggested that phosphorus might be more toxic by mouth than by injection, but the liquid media used in the two series of experiments were not the same. Therefore, additional feeding tests were conducted on 40

insects with phosphorus suspended in the physiological salt solution. The M.L.D. appeared to be less than 0.03 mg. per gm. and consequently it is probable that phosphorus is more toxic by mouth than by injection. Only the difficulty of maintaining a uniform suspension of the particles in the salt solution prevents a more positive expression of this conclusion.

The contact action of phosphorus paste was tested in the manner described by Munger and Siegler (1937) for sodium fluoride; i.e., the paste painted upon the body was kept away from the head and mouth-parts by inserting the head of the cockroach through a hole in rubber dental dam stretched over one end of an open tube. The treated body of the cockroach rested within the tube, which was placed horizontally within a small observation cage. Untreated checks and those treated with unpoisoned paste were held in the same way. Neither the treated nor check insects received food or water.

The mean survival period of 52 insects treated on thorax and ventral aspect of the abdomen, on venter of the abdomen, or on part of the venter of the abdomen not covering the spiracles was 1.8 days. The mean survival period of 25 insects treated in the same way, but with paste without phosphorus was 5.6 days. The mean survival period of 9 untreated insects was 12.6 days. It is therefore concluded that the paste without phosphorus was toxic to the insects, but that the presence of phosphorus increased its toxicity so that phosphorus can be said to exert a toxic effect when in contact with the surface of the body.

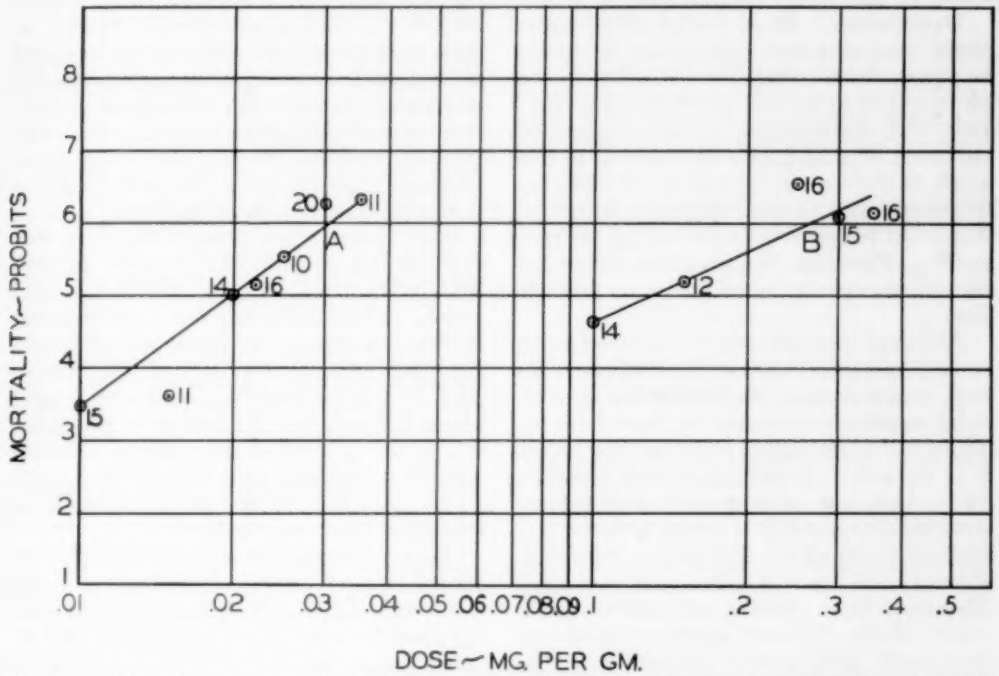


FIG. 2.—Relation between dose of phosphorus and mortality of large nymphs of the American cockroach (A) and the German cockroach (B). Probit 5 is equivalent to 50 per cent mortality.

It was realized that phosphorus in contact with the surface of the body of the cockroach might really be acting in the vapor phase. Accordingly tests were made in stoppered vials to detect action in the vapor phase. A small, short vial containing undiluted phosphorus paste was covered with screen and placed within a larger vial. A cockroach was placed upon the screen so that it could not come in contact with the paste and the larger vial was stoppered. Check tests were made in the same way with unpoisoned paste. The test roaches were held for observation without food or water.

Among the 52 insects exposed to fumes from phosphorus paste, nearly all died in less than a day. Check insects over paste

without phosphorus lived more than ten days. It is thought that phosphorus vapor or oxides of phosphorus may act in the vapor phase. The possibility that the oxidation of phosphorus may affect the insects by depleting the oxygen supply within the vials and by desiccation of the insects should also be considered. Although the nature of the effect is not known, it is certain that cockroaches cannot long survive exposure in a small closed space in proximity to phosphorus paste.

DISCUSSION.—In so far as phosphorus paste acts as a stomach poison it should be remembered that the M.L.D. of the phosphorus in it will depend on the particle size distribution of the suspended particles. The M.L.D.'s determined in this work therefore apply not to phosphorus in general, but to the particular sample of dispersed phosphorus used in the investigation. Possibly the contact effect of phosphorus paste depends also on particle size.

Although phosphorus is now used as an insecticide only against cockroaches, its high toxicity suggests that other insecticidal applications could be found for it. Time and opportunity were lacking to try it in cutworm, grasshopper and silverfish baits, but, out of curiosity, a few tests were made against leaf eating insects, *i.e.*, the last instar of the southern armyworm, *Prodenia eridania* (Cram.) and the adult Mexican bean beetle, *Epilachna varivestis* Muls. Neither species would eat cranberry bean leaves treated with the diluted paste. By forced feeding the southern army worm was killed by phosphorus paste, which caused violent regurgitation of the contents of the alimentary tract. Whether phosphorus could be used on plants as a protective insecticide is unknown, but the supposition that it might be dangerous to plants and to man and animals should not prevent experimental study of the question. The senior author suffered no ill effects from daily work with phosphorus paste during half a year.

SUMMARY.—For a study of the toxicology of phosphorus against large nymphs of the American and German cockroaches a commercial, 2 per cent phosphorus paste was used as the source of phosphorus. In this product phosphorus is finely dispersed and suspended in a viscous medium.

By quantitative feeding of phosphorus paste diluted with syrup, the median lethal dose of phosphorus for the American cockroach was found to be 0.02 mg. per gm. showing that it is a highly toxic stomach poison for this species. Phosphorus was much more toxic to the American cockroach than was sodium arsenite or sodium fluoride when the latter were fed in the same viscous medium and phosphorus was imbibed more rapidly and with less regurgitation than were the other two poisons. Sodium arsenite was more toxic in water than in syrup, but even in water it was less toxic than phosphorus.

The German cockroach was less susceptible to phosphorus in paste diluted with syrup than was the American cockroach, the M.L.D. for the former being 0.13 mg. per gm. as compared with 0.02 mg. per gm. for the latter. The larger M.L.D. for the German cockroach cannot alone account for the failure of phosphorus paste to control this species in practice. It is probable that the German cockroach does not imbibe paste as freely as does the American cockroach.

Studies were made of the effect of phosphorus in paste, when administered to the American cockroach by injection, by contact and by exposure to fumes. Phosphorus in paste, diluted for injection with a physiological salt solution, appeared to be somewhat less toxic than when administered by mouth in the same medium. Phosphorus in paste killed cockroaches when painted on the body, the mouthparts being shielded from contact with the paste. In a small closed space, cockroaches were killed within 24 hours by phosphorus paste with which they were not in contact. It is not yet known whether this effect was due to the action of phosphorus vapor, or to depletion of oxygen by oxidation of the phosphorus, or to desiccation of the insects by the oxides of phosphorus.—9-14-39.

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# SCIENTIFIC NOTES

## Mounding Peach Trees Following Applications of Ethylene Dichloride Emulsion and of Paradichlorobenzene Crystals

The statement is frequently made that peach trees treated with ethylene dichloride emulsion for control of peach borer need not be mounded or that mounds if applied need not be so large as for those treated with paradichlorobenzene crystals (P.D.B.). Tests were conducted in Illinois in the spring and fall of 1939 to determine the correctness of the first statement and in the fall of that year to test the second. Ten-tree plots were treated with one-half pint of 20 per cent ethylene dichloride emulsion and others with 1 ounce of P.D.B. using 10 to 12 year old peach trees. Both spring and fall treatments were repeated in 10 to 14 days. A summary of results follows:

**Table 1.—Value of mounding for treated peach trees.**

| Plot | | Number Trees Treated | Total Number Borers | Per Cent Dead |
|---|---|---|---|---|
| | *Spring Treatments* | | | |
| 1 | Ethylene dichloride, mounded | 20 | 118 | 89.8 |
| 2 | Ethylene dichloride, not mounded | 20 | 102 | 70.9 |
| 3 | Check | 10 | 74 | 1.1 |
| | *Fall Treatments* | | | |
| 1 | Ethylene dichloride, mounded 3 in. | 20 | 30 | 93.4 |
| 2 | Ethylene dichloride, not mounded | 20 | 49 | 44.9 |
| 3 | P.D.B. crystals, mounded 3 in. deep | 20 | 56 | 96.4 |
| 4 | P.D.B. crystals, mounded 1 in. deep | 20 | 73 | 80.9 |
| 5 | P.D.B. crystals, not mounded | 20 | 38 | 2.7 |
| 6 | Check | 5 | 12 | 0.0 |

It seems plain from these tests that for best efficiency trees treated with ethylene dichloride emulsion need mounding. In the spring treatments about 20 per cent fewer borers were killed, and in the fall about 50 per cent, where the trees were not mounded. In the spring heavy rains followed within a day after treatment, a frequent occurrence during the usual periods of treatment. It was thought that rains had washed some of the material from the unmounded trees causing the decrease in efficiency. In the fall, however, treatments were applied during a period of drouth and the records show still poorer results in unmounded trees, so there is a possibility that spring rains carried the material into the ground.

It would appear from the fall treatments that mounds need not be large around trees treated with P.D.B. crystals, no larger than for ethylene dichloride. Three inches is about the minimum amount of dirt that would be thrown against a tree, using a long-handled shovel in the ordinary operation of mounding. Plot 4 counts showed that even with a mound one-inch deep fairly good kill of borers was obtained; 81 per cent. It is plain also from Plot 5 that poorer results are to be expected if no mounds are made after P.D.B. than after ethylene dichloride.—11-8-39.

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## A New Pest of Hollyhock (*Anthomyza angelicae* Frost)

In the fall of 1938 hollyhock flower stalks were observed to be mined extensively by larvae which pupated in the lower six inches of their length. At the time (September 18) only two out of approximately 100 insects were larvae. As many as 35 pupae were found in one stalk. Flies emerged from pupae kept in the laboratory from January 10 to March 1. These were identified by S. W. Frost as *Anthomyza angelicae* Frost. The species was described (Frost, 1934) from Ithaca on *Angelica atropurpurea* and has also been found at Pacific Grove, California.

During early June of 1939 adult flies were seen on the hollyhock plants. Egg punctures among the lower flower buds were first observed on June 8. Egg laying continued for several days and larval tunnels began about June 25. The course of these tunnels from egg puncture to pupa is visible in September. The total distance traveled by the larvae sometimes exceeds six feet, although the flower stalks are only about three feet high when the eggs are placed. The injury is of a vitiating rather than a lethal type, plants growing and flowering almost normally except for early drying up of the flower stalks in the late summer.

Parasites which emerged from the pupae concurrently with the adults during January and February, 1939, were identified by A. B. Gahan as *Syntomopus americanus* Ashm.—11-18-39.

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## Some Newly Discovered Habits of the Codling Moth

Early in the spring of 1939 a Benoni apple tree with a heavy set of fruit was screened with a good grade of cheese cloth. This tree was approximately 18 feet high and 18 feet wide. It received the scab and calyx sprays only. The straw mulch and all vegetation was removed from beneath the tree leaving the ground bare and smooth. Thirty-five codling moths (not determined as to sex) were put on the tree May 18 and on May 30 new entries showed clearly that this tree would be heavily infested.

All the drops that were found beneath the tree were picked up at intervals, counted and examined for worms. There were 2,804 apples picked up from the ground and they showed 7,844 worm entrances. On July 29 the drops were picked up for the last time. There were 163 of them and they contained 453 entrances. At the same time the apples remaining on the tree were picked and examined. There were 566 of these and they contained 1,732 worm entrances. Of the entire crop there were 537 clean fruits and a total of 2,996 apples that had one or more worms in them. If the entrances from the three lots of fruit are totaled it will be seen that there were 10,029 entrances in 2,996 fruits from a total crop of 3,533 apples.

The record of this tree shows something of the biotic potential of the codling moth when the insect has favorable conditions. It should be recalled, moreover, that only half the codling moth's active season had passed at the time this Benoni crop ripened. In that time, assuming that half the original number of moths (18) were females this insect multiplied more than 557 times. If this should have continued at the same rate for the remainder of the season there would have been more than 5,585,596 individuals.

At the time the first worms were maturing and leaving the apples to pupate a sticky band was applied to the inside of the wooden frame holding the screening to prevent the larvae from escaping. The tree was not scraped but a sticky band was put around the trunk at the surface of the ground. Similar bands were applied at 18-inch intervals on the larger branches. All limbs three inches or more in diameter were banded.

It was surprising to note that the larvae would, when mature, not being able to cross the sticky bands, pupate on the surface of the ground even though all the vegetation had been removed, and successfully emerge as moths. Many were found pupating on small clumps of grass roots. A number of larvae pupated on the bare surface of the ground without making a cocoon. Relatively few larvae were trapped in the sticky bands and it was observed that even though these bands occurred every 18 inches on the trunk many of the larvae were able to find their way to the areas between the bands to pupate. The only explanation as to how this was accomplished is that they must have swung from a silken web against the trunk and so made contact. Pupation took place in every conceivable place on the tree from the crown to the tips of the branches, and although, in the majority of cases, some cover, such as bark, dead leaves, earth, and cracks in branches, was sought this was not always the case.

At the time the apples were removed from the tree (July 29) a heavy hatch of eggs was in progress. Removal of the last of the fruit did not interfere with this hatch. The newly hatched larvae not finding fruit to enter went into fruit spurs, sap shoots at leaf bases, new breaks in twigs or small branches, enlargements caused by the feeding of wooly aphids, and into the enlargements on fruit spurs where apples had been attached. Counts showed that at least 500 larvae had begun to develop in such places. Feeding started just beneath the bark and as the larvae developed they also consumed considerable amounts of wood at the center of the twigs. As they became older it was not uncommon to see hanging from the openings in the twigs in which they were feeding, masses of brick colored frass. By this excrement it was not difficult to locate the larvae. Examinations of bands on this tree showed that mature larvae were seeking cocooning quarters by September 25. A considerable number of these larvae matured and went under the bands of this tree.

Through this study, habits of the codling moth unknown until now, have been brought to light. We know now that codling moth larvae under such abnormal conditions mature on:

1. Fruit buds.
2. Fruit spurs.
3. Sap shoots.
4. Four year old growing apple wood.
5. Apple mummies not rotted but shriveled and dried up on the ground, having laid there a year or more.
6. On leaves alone (According to T. J. Headlee and the late Anthony Spuler).—1-16-40.

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## Some South Sea Island Aphids

Specimens of the melon aphid, *Aphis gossypii* Glover, recently collected on *Portulaca lutea* on Enderbury Island, one of the group of the Phoenix Islands in the South Pacific, by Ashley Brown on October 12, 1939, is another indication of the introduction of aphids into this great tropical area. The fact that many indigenous species have been described from Maylasia by Van der Goot and Takahashi suggests that perhaps there are many new species yet to be discovered on the islands of the Pacific.

A single indigenous species, *Anomalaplus comperei* Pergande, collected on *Acacia* and *Eucalyptus*, February 18, 1907, at Albany, West Australia, by Geo. Compere, appears to be the only native aphid so far reported from Australia. Another species, *Aphis coprosmae* Laing,* on *Coprosma*, reported by Tillyard (1927), is thought to be indigenous to New Zealand. Takahashi has described *Aphis mumfordi* from Hivaoa, Marquesas (1934) and *Neophyllaphis araucariae* on *Araucaria cunninghami* from Mauritius (1937). From Micronesia (1936) he has also listed the mealy plum aphid, *Hyalopterus arundinis* (Fab.), on *Phragmites*, and the bamboo aphid, *Oregma bambusae* Buckton, on bamboo, from Palau Islands; the laburnum aphid, *Aphis laburni* Kalt., on peanut and bean; the melon aphid, *A. gossypii* Glover, on cotton and watermelon, and the banana aphid, *Pentalonia nigronervosa* Coquerel, on banana

* A description of this species ascribed to Laing by Tillyard (1926) was never published by Laing and so the species must therefore be credited to Tillyard.

from the Marianna Islands. Fullaway (1910), in Hawaii, has described nine genera and twenty-one species of which three were new. His list includes most of the common species which occur in the South Sea Islands.

In a list for this great Pacific Region the following species should be mentioned as being the most important.

The oriental citrus aphid, *Aphis citricidus* (Kirkaldy) (1907), is widely distributed throughout tropical Africa, Asia, and the South Sea Islands. It feeds on *Citrus* spp., *Bidens pilosa*, *Murraya exotica*, etc. *Aphis tavaresi* Del Guercio (1908) and *A. citricola* Van der Goot (1912) appear to be synonymous of this species.

The melon aphid, *Aphis gossypii* Glover, occurs throughout much of the world and especially in the tropical and subtropical regions. The hosts are very numerous. It may possibly be indigenous in certain parts of Oceania.

The corn leaf aphid, *Aphis maidis* Fitch, is common on corn, sugar cane, and related plants.

The sugar cane aphid, *Aphis sacchari* Zehntner, frequently attacks sugar cane, corn, sorghum, and related crops.

The black citrus aphid, *Toxoptera aurantii* (B. de Fonsc.), is one of the commonest species in the tropics and is a general pest of *Citrus* spp., *Camellia* spp., *Theobroma cacao*, *Coffea* spp., *Cinchona* sp., *Mangifera* sp., *Ficus* spp., and a large number of other plants.

The banana aphid, *Pentalonia nigronervosa* Coquerel, feeds on *Alpinia* spp., *Alocasia* sp., *Arum* sp., *Hedychium* sp., *Musa* sp., and similar tropical plants.

The fern aphid, *Idiopterus nephrelepidis* Davis (*Macrosiphum kirkaldyi* Fullaway) is often abundant on ferns. It might will be indigenous to Hawaii where it has been taken in the mountains on the native fern, *Elaphoglossum reticulatum* (Gaud.).

The green peach aphid, *Myzus persicae* (Sulzer), is becoming rapidly disseminated throughout the world and has found the tropics quite acceptable, but perhaps not so congenial as the subtropical and warmer temperate regions. Therefore it is more abundant in the northern and southern limits of the South Sea Island areas.

The mealy plum aphid, *Hyalopterus arundinis* (Fab.), occurs generally in the tropics and may spend much of the year on peach and other fruit trees of the genus *Prunus* which hold their leaves almost the entire year in those regions. It is also common on *Phrygmites* spp., *Scirpus* spp., *Philaris* sp., *Arundo* spp., and *Sparganium* sp., and similar hosts.—12-11-39.

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## A Brazilian Parasite of *Pseudococcus maritimus* (Ehrh.)

On December 6, 1934, Compere (1937) sent to Riverside, California, a few mealybugs which he found lightly infesting *Hedera helix* at Avenida Paulista, Sao Paulo, Brazil. On December 23, five days after the shipment was received, three females of *Aenasius paulistus* Comp. emerged. In order to determine the host species, a stained preparation was made of the remains of one of the mealybugs from which the parasite had emerged. It had the diagnostic characters of *Pseudococcus maritimus*. The parasite females, therefore, were provided with *P. maritimus* collected from grapefruit trees at Riverside. Oviposition occurred on December 25, 1934. A parasitized mealybug mummified on January 8, 1935, and a male *Aenasius* emerged from it on January 20. A total of four males was reared.

On January 20, however, only one of the original three females was alive. Although it was mated with one of the males, no progeny resulted and the stock was lost. Apparently, as is often the case, gravid females that are held for three weeks or more at warm temperatures and are not permitted to oviposit, lose the ability to reproduce.

In Sao Paulo, where the climate is comparable to that of Los Angeles, California, Compere (1937) found a few plants infested with *Pseudococcus maritimus* but no evidence of parasitism. The disappearance of these infestations, which occurred within a few months, is attributed by Compere to an invasion of insect predators.

Compere (1937) first observed that the mealybug from which *Aenasius paulistus* was reared was not *maritimus* but a species which had the usual diagnostic characters of *P. maritimus* but in life resembled *P. gahani* Green. The mealybug host of *A. paulistus* was later described by Hambleton (1935) as *Pseudococcus sociabilis*, a species infesting *Hedera helix* and *Erythrina reticulata*.

Since in California *Pseudococcus maritimus* is a serious pest of pears in the San Francisco Bay region, live specimens of *Aenasius paulistus* are desired for propagation.—1-6-40.

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## Epidemics of Fungus Disease Control Insect Pests in Puerto Rico

In a large planting of velvet beans at the Isabela Sub-Station this fall, an extensive outbreak of the

common velvet bean caterpillar, *Thermesia gemmatilis* Hübner, completely defoliated the plants as they were maturing pods. Of a large sending of the caterpillars made to this laboratory on October 23, over half were dead upon receipt, being covered with a thick coating of whitish to pale greenish-blue fungus. The fungus infection had occurred before the caterpillars had been collected and shipped, however, for in the field they were also to be seen in large numbers dead and mummied on the stems of the plants; often as many as eight or ten on a single bush. The weather at the time was warm and humid, often with numerous sharp showers (and invariably with at least one) each day. To be sure, the disease epidemic had arrived too late to save the crop, but it was none the less effective in killing all the last instar caterpillars. The fungus has been identified by Miss Vera K. Charles as "*Botrytis rileyi*, now *Spicaria rileyi*. It is closely related to *Spicaria prasina* (Maub.) Saw., in which the spores are oval. Doctor Wolcott's material seems intermediate between these two forms." A similar question of the specific identity of the fungus attacking this host has also been noted in Florida.

A previously recorded instance in Puerto Rico of insect control by fungus disease is of the cottony cushion scale, *Icerya purchasi* Maskell, by another *Spicaria*, which Mr. E. West of the Florida Station stated was identical with what they called *Spicaria jaranica*. Control was 100 per cent perfect in certain citrus groves well protected by hills and bamboo windbreaks, as at Pueblo Viejo in August 1923, so perfect indeed that the scale has never since been found there. Elsewhere the effectiveness of the fungus varied from almost perfect in some groves in pockets in the hills around Bayamon and those with dense windbreaks near the beach at Palo Seco, to zero on the coast, at Dorado, in a grove with only casuarinas for windbreak. Both of these epidemics emphasize the vital importance of ecological conditions in the effectiveness of fungus control.

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## A Tachinid Parasite of the Puerto Rican Changa

In June 1939, in the last week of collection at Belem, Pará, Brasil for shipment to Puerto Rico of the wasps *Larra americana* Saussure, which are parasitic on the changa, *Scapteriscus vicinus* Scudder, one changa (out of the hundreds that were being used for oviposition by *Larra* wasps in the laboratory) was found dead in its can, and beside it a large stout Dipterous puparium with two large black knobs. Eleven days later (in Puerto Rico), a sluggish yellow Tachinid fly with pink eyes emerged. This was later determined by Dr. D. G. Hall as *Euphasiopteryx australis* Townsend. One more changa in Belem and several *en route* were found thus parasitized, giving approximately an indicated parasitism of 0.5 per cent by these Tachinids at the beginning of the dry season, but no indication of their real parasitism, for the changas were kept in captivity at most only a week, or of what it might later become with the advance of the dry season. This is the first published record of a dipterous parasite of the Puerto Rican mole-cricket, although Dr. Townsend reports three puparia of an allied species reared from a cricket at College Station, Texas, and Mr. E. G. Smyth writes me that he has reared this or an allied species from a green katydid, *Neoconocephalus* sp., at Central Cartavio, Trujillo, Peru.

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## A Coccinellid Introduced into California

Koebele (1893) reported that of all the scymnids found in Australia, *Scymnus flavifrons* Blackb. was one of the smallest and most common. It appeared to feed on various coccids. He found it "at Toowoomba, Queensland, upon orange infested with red and black scales; upon *Acacia* infested with an *Aspidiotus*, and on *A. eucalypti* Mask., upon eucalyptus; at Gosford, New South Wales, upon *Cyncarpia laurifolia* infested with *Aspidiotus cyncarpiae* Mask., and *Chionaspis eugeniae* Mask., near Sydney and at Mount Victoria, upon *Leptospermum laevigatum* F. v. Mueller, feeding here in very large numbers—both in larva and imago state—upon *Eriococcus leptospermi* Mask. It was always numerous at Parramatta, and from a lot of larvae and pupae saved from a small bush infested with *Lecanium cassiniae* Mask. parasites were bred from the larvae and most of the pupae were found infested with a small chalcid."

In 1931, *Scymnus flavifrons* was again introduced into California, being reared from black scale material sent by me from Sydney, New South Wales, to Professor H. S. Smith at the University of California Citrus Experiment Station, Riverside, California.

The adult female is black and about 1 mm in length. The appearance of the male is like that of the female except that the frons are yellowish brown.

The egg is unlike many coccinellid eggs in being almost flat. It is twice as long as wide. The chorion is finely punctate and pliable. The egg contents appear yellow or green through the chorion.

The newly hatched larvae are active and attack young scale and mealybugs. After they commence to feed, they become sluggish.

The general body color of the larva is dark gray. The nearly mature larva is marked by two longitudinal whitish stripes on the abdomen, extending back to the sixth segment and dividing the dorsum into three equal dark gray areas. In the mature larva the center area is distinctly purplish brown, and the spiracles are surrounded by waxy, white, smooth impressions.

The pupa is light yellow and hairy, with a semitransparent exoskeleton.

At temperatures between 75 and 80 degrees F., the life cycle is four to eight weeks. When development is rapid, the egg incubation period is six days, the larval period 15 days, and the pupal period seven days.

The species is not known to be established in California.

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## Male Scale Injurious to Olives

Although there is little recorded information with regard to the subject, it is generally considered that male coccids are practically of no importance so far as injury to plants is concerned. However, during the course of experimental work dealing with the life history and control of the olive scale, *Parlatoria oleae* (Colvee), on olives near Fresno, California, it has been observed that extensive damage is caused by the male scale.

Both male and female scales produce a black spot, roughly circular in outline, upon the surface of the fruit. These areas, with the scale as a center, vary from 1 to 4 mm. in diameter, and the discoloration extends well below the surface into the flesh. Olives thus affected are unfit for pickling and may or may not be pressed for oil, depending upon the variety involved

The sex ratio is markedly in favor of the males and mortality is quite low. In the case of this coccid the males are at least as distinctive as the females and may well be the more important sex in terms of damage to olive fruits.—12-6-39.

E. L. WAMPLER, *University of California, Berkeley, Calif.*

## Activities of the Adult White-Fringed Beetle in New Orleans and Vicinity from September 1938 to May 1939

The white-fringed beetle (*Pantamorus leucoloma* (Boh.)) was discovered in New Orleans, La., the latter part of 1937, by officials of the U. S. Department of Agriculture. Adults of this insect, which had previously been observed in other areas in the Gulf States, were reported by Young and App (1939) to be found in 1937 as late as December 18, in 1938 as late as December 7 in an infested area at Florala, Ala.

In the milder climate of New Orleans and vicinity the insect may be found throughout the winter in the adult stage, as evidenced by collections at intervals from September 1938 to February 1939. Table 1 shows the months in which adults, pupae, and larvae were collected in the field from September 1938 to May 1939. The purpose of the table is to present information as to when the different stages were found and not to indicate their relative abundance.

Adults collected and caged under natural weather conditions to serve as exemplary specimens laid viable eggs when fed on such natural host plants as goldenrod, bloodweed, and blackberry (Table 2). To illustrate, an adult collected February 1, 1939, lived 102 days after that date, or until May 14, and laid 652 eggs, some of which were viable under natural weather conditions, during the period February 10 to May 10. Because no pupae were found from the first of September, 1938, until the following April, among 78,157 larvae collected from the soil, it may be reasonably surmised that this adult emerged prior to September, and that its adult life span reached from at least September 1 until May 10, inclusive, or a period of 252 days. Another adult beetle collected February 2 lived 81 days after that date and laid 611 eggs during the period February 9 to April 7, representative lots of which showed a viability of 47.62 per cent under natural weather conditions. The probable minimum longevity of this adult was at least 236 days. A third adult collected February 14 lived 78 days after that date and laid 742 eggs during the period February 14 to April 27, representative lots of which had a viability of 55.22 per cent under natural weather conditions. Four other adults, collected January 26 and 31 and February 10 and 15, lived after the dates of collection 76, 20, 39, and 35 days, but laid no eggs.

**Table 1.—Collections of white-fringed beetle adults, pupae, and larvae in New Orleans and vicinity from September 1938 to May 1939.**

| Month | Adults Collected* | | Pupae Collected | | Larvae Collected | |
|---|---|---|---|---|---|---|
| | Days | Number | Days | Number | Days | Number |
| September | 13 | 400 | 0 | 0 | 20 | 7,310 |
| October | 8 | 156 | 0 | 0 | 18 | 10,974 |
| November | 8 | 31 | 0 | 0 | 18 | 14,717 |
| December | 9 | 13 | 0 | 0 | 16 | 14,165 |
| January | 10 | 11 | 0 | 0 | 23 | 16,684 |
| February | 6 | 6 | 0 | 0 | 19 | 7,846 |
| March | — | — | 0 | 0 | 13 | 6,461 |
| April | — | — | 10 | 48 | 25 | 6,835 |
| May | 17 | 58 | 26 | 529 | 26 | 7,449 |
| Total | 71 | 675 | 36 | 577 | 178 | 92,441 |

* No attempt was made to collect adults during March and April.

**Table 2.—Longevity and egg-laying records of adult white-fringed beetles collected during the winter of 1938–39, New Orleans, La.**

| Date Collected | Longevity After Collection, Days | Egg-Laying Period | Number of Eggs Laid | Approximate Percentage of Eggs Hatched |
|---|---|---|---|---|
| Jan. 26 | 76 | — | 0 | — |
| 31 | 20 | — | 0 | — |
| Feb. 1 | 102 | Feb. 10–May 10 | 652 | Some* |
| 10 | 39 | — | 0 | — |
| 14 | 78 | Feb. 14–Apr 21 | 742 | 55.22 |
| 15 | 35 | — | 0 | — |
| 21 | 81 | Feb. 9–Apr. 7 | 611 | 47.62 |

* Exact percentage was not determined.

No effort was made to obtain records of oviposition under natural conditions by beetles collected prior to February 1, although it was observed that such beetles laid eggs readily in an unheated greenhouse during the latter part of December and in January.

In regard to the presence of pupae in the field during the fall, winter, and spring extensive soil sampling for larvae and possible pupae showed that during the period September to March 78,157 larvae were taken from the soil without the collection of a single pupa. In the spring the first pupa

was collected on April 13, and early in May adult beetles began to appear in the pupal cells in the soil and later on the vegetation above. The records given in table 1 of adults collected include only individuals found above ground. The first adult found above the soil in the spring was collected on May 11, and since it had not yet lost its mandibular cusps it had probably not long left the pupal cell.

In conclusion it may be stated that the data presented show that adults of the white-fringed beetle, which evidently emerged prior to September 1938, were present in the infested area in New Orleans and vicinity until May 14, 1939. Since the date on which the last wintering beetle died (May 14) was later than that on which the first beetle was collected after pupation began in the spring (May 11), there was no interval during the fall, winter, and spring of 1938–39 when the adult was not present.

E. M. LIVINGSTONE and GEORGE R. SWANK, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine.*

LITERATURE CITED

**Young, H. C.,** and B. A. App. 1939. Biology of the white-fringed beetle (*Naupactus leucoloma* Boh.). U. S. Dept. Agr. Bur. Ent. and Plant Quar. **E-464.** 22 pp., 3 figs. Feb. (Mimeographed.)

## The European Earwig in Utah

The European earwig, *Forficula auricularia* Linn., is now well established at Farmington, in Davis County and on some nearby farms. Its presence there was first called to the writer's attention by County Agent J. H. Blazzard on June 30, 1938. Large populations were found to be present around homes and on various farms. Reports indicate that the pest has been present and causing annoyance in some homes since approximately 1930, suggesting that it must have been brought into Utah even earlier.

A single specimen of this pest identified by A. B. Gurney as *F. auricularia* L., was collected at Holladay, in Salt Lake County, during 1937 by Dr. C. F. Smith and the writer. A partial survey of the Holladay and surrounding areas of Salt Lake County, made during 1939, disclosed the presence of this earwig in annoying abundance upon a number of farms as well as around homes and grocery stores in parts of the Holladay-Cottonwood area. Numerous reports of annoyance in homes as well as to fruit and flowers were received from the infested areas during 1939.

Through the cooperation of the U. S. Bureau of Entomology and Plant Quarantine, *Bigonicheta setipennis* Fall flies were shipped from Puyallup, Washington by air express on May 15, 1939, the material being released at Farmington on May 16. All but three of the parasites shipped were alive when the release was made. A few puparia of this parasite were found during examinations of the twenty earwig-parasite traps operated in the orchards where the releases were made.

On June 5, 1939, a second shipment of *B. setipennis* was sent from Puyallup; 38 females and 1 male were released at Cottonwood and 71 females were released at Holladay on June 6.

Very little direct control appears to have been attempted as yet in infested localities of Utah. A few home owners have put out poisoned bran bait under burlap sacks and one man poured used crankcase oil upon colonies wherever he found unusually heavy populations of the earwigs on his property.

G. F. KNOWLTON, *Utah Agricultural Experiment Station, Logan.*

## Control of Black Peach Aphis

Severe losses to newly planted peach trees frequently occur when trees are set on land which has been in peaches for a number of years. Dr. C. R. Cutright of the Ohio Agricultural Experiment Station expressed the opinion that the remedy lay in planting trees in soil brought in from outside the orchard. This plan was tested by an Illinois grower with the following results:

In the fall of 1937 the old peach orchard was removed a new one planted in the same place in the usual manner. Result: 50 to 75 per cent dead or sickly and infested with black peach aphis, *Anuraphis persicae-niger* (Smith) which I found to be doing severe injury to roots.

In the fall of 1938 much of the orchard was reset, using 2-year old trees from another aphis-infested part of the orchard, but placing soil from outside the orchard in holes dug for trees. In the spring of 1939 another section of the orchard was reset with trees from another source not infested, but placing soil from outside the orchard as in fall. Seven of these new trees were set in the spring of 1939 in the part set in fall, but no new dirt was placed in the holes. Examinations were made at intervals, and by October 1939 both lots of trees set with new dirt were looking thrifty and had very little infestation. The seven trees not so set were dead, dying, or sickly, and all infested. The obvious conclusion is that the system of resetting with new soil is successful in Illinois.

In the fall of 1938 lots of infested trees were treated with the following materials: ethylene dichloride emulsion, ¼ pint to each tree at 10 and 20 per cent strength; paradichlorobenzene (P.D.B.), ½ ounce crystals, and also dissolved in *Dendrol* and diluted so each pint contained one ounce, and consequently each tree received ¼ ounce of dissolved paradichlorobenzene. Table 1 shows results:

**Table 1.—Chemical control of Black Peach Aphis.**

| Plot No. | Treatment | Aphids Per Cent Dead | Injury |
|---|---|---|---|
| 1 | Ethylene Dichloride 10% | 1.6 | None in 10 trees |
| 2 | Ethylene Dichloride 20% | 4.9 | One in 5 trees |
| 3 | P.D.B. crystals, ½ oz. | 100.0 | None in 10 trees |
| 4 | P.D.B. in *Dendrol* | 100.0 | None in 10 trees |
| 5 | Check, no treatment | 0.0 | None in 5 trees |

It would appear that paradichlorobenzene either in crystals or dissolved in oil is effective for control of aphids but that ethylene dichloride emulsion at strengths that will not injure the trees is not effective. These counts were made on main tap root and roots nearby, as it was not possible to dig up the trees to examine roots all through the ground. Aphids as much as two feet away from the trunk were not reached by the materials. P.D.B. was placed in a ring two inches from the trunk for maximum spread of gas. The liquids were applied to the trunk but spread out at least two inches.

S. C. CHANDLER, *Illinois State Natural History Survey Division, Urbana, Ill.*

JOURNAL OF ECONOMIC ENTOMOLOGY

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## *Theodore H. Frison*

FOUR years ago the first editor of the JOURNAL, Dr. E. Porter Felt, retired. For 28 years he had given the Association unselfish and faithful service and had well earned release from the heavy burden of editorial duties that he had borne practically unaided.

To succeed Dr. Felt, who became and remains honorary editor, the Association elected Dr. Theodore H. Frison, Chief of the Illinois State Natural History Survey. This appointment came to Dr. Frison without warning. He could well have declined it for the reason that his administrative duties and his personal research required all his time. However, putting aside his own inclinations, he agreed to carry out the wishes of the Association to the best of his ability for a limited period of time. There lay before him not only the task of carrying on the good work of Dr. Felt but of putting into practice new editorial policies desired by the Association. During the past four years members of the Association have become accustomed to the review of manuscripts by members of the Publications Committee and, as much correspondence was required to carry out this policy, the work of the Editor was increased. Moreover, Dr. Frison took it upon himself to find a printer and a format that would give the Association the most for its money. The change to the double column format was made two years ago, effecting great economies without detracting from the appearance of the JOURNAL. Although this was the most obvious improvement made by Dr. Frison, many other changes were made that may have escaped the notice of members of the Association. A consistent, uniform style has been evolved that necessitates careful editorial work upon each manuscript to cast it in the form adopted. In general, it has been Dr. Frison's policy to put every acceptable manuscript into JOURNAL form and, so far as possible, to detect and eliminate faults.

The approach to perfection in quality and style of JOURNAL manuscripts is to be ascribed largely to the ideals, determination and executive ability of Dr. Frison. Applying nearly all his leisure time to the JOURNAL at the expense of his own research, he worked continually to achieve his vision of a JOURNAL that would reflect the greatest credit upon the Association. But he could not have reached his goal alone. By his own example he caused the members of the Publications Committee to give him loyal support, and he enlisted in the work members of his own staff who gave their time and effort for very little compensation. The Association may not realize how much it owes to the clerical staff of the Natural History Survey and to Dr. Frison's editorial assistants; first, Carroll Chouinard and later, James S. Ayars. Finally the members of the Association themselves have helped to raise the standards of the JOURNAL by preparing their manuscripts in conformity with the policies established by Dr. Frison.

Dr. Frison remained Editor of the JOURNAL longer than he had intended. Feeling that he had kept his promise to the Association and that his own official and private affairs required more attention than he had been able to give them while Editor, he offered his resignation, which was accepted with the greatest reluctance. Few servants of the Association have done so much for it as did Dr. Frison during the four years of his editorship.

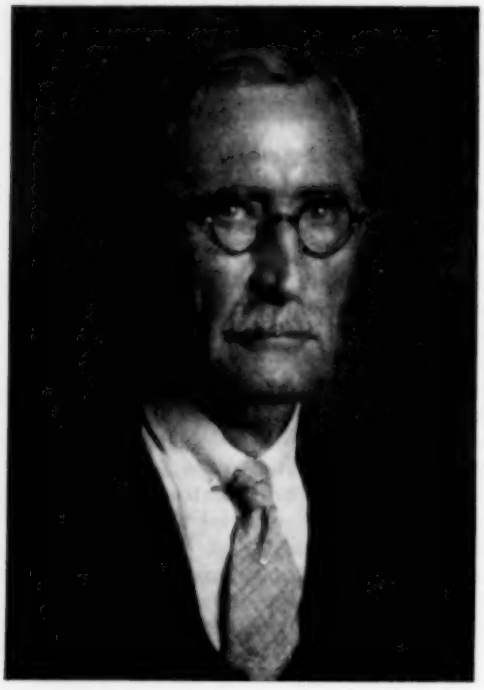
The Association is again fortunate in obtaining the services of another unselfish and capable entomologist as Editor of the JOURNAL—Dr. L. M. Peairs. With our able Associate Editor, Harry B. Weiss and Business Manager, Ernest N. Cory, continuing, and with the cooperation of all members of the Association we may expect the JOURNAL to go forward along the lines laid down by Dr. Felt and largely perfected by Dr. Frison.—1-15-40.

THE PUBLICATIONS COMMITTEE

# OBITUARY

## Charles Nicholas Ainslie, 1856–1939

Charles Nicholas Ainslie, American entomologist, whose death occurred at Sioux City, Iowa on December 5, 1939, was born October 13, 1856, near Amsterdam, New York. He was the second son of George Ainslie (1824–1885) and Mary Jane (Hageman) Ainslie (1833–1861). His father, a native of Roxburyshire, Scotland, was for several years a Presbyterian missionary to the Choctaws in Indian Territory, where the son's early life was spent until the outbreak of the War of the Rebellion. Then the father returned for a brief period to New York State, spent a short time in Scotland, and still later, in 1862, relocated his family in the then frontier settlement of Rochester, Minnesota. There the son grew to manhood under conditions quite similar in primitiveness to those of his early childhood. He received his earliest training from his step-mother and as a result was able to attend the Rochester High School. Later he secured a scholarship at Beloit College from which he was graduated A.B. in 1877, and A.M. in 1880. After a few months in performance of various kinds of temporary work, he secured a position in 1881 in one of the banks in Rochester. On October 9, 1884 he married Miss Ada Gooding of Rochester. Their children were: George G. (1886–1930), Arthur F. (1889– ) and Kenneth C. (1894– ). After some three years of banking experience, he was able to secure a much better place in a larger banking institution in Rochester. In this, he remained until 1906, during which 22-year period he advanced to the position of assistant cashier and continued an active interest in entomology which began in his boyhood. He began his professional entomological service with the United States Government August 1, 1906, under the leadership of Professor F. M. Webster, in charge of the division of Cereal and Forage Insect Investigation of the then Bureau of Entomology of the Department of Agriculture.



CHARLES NICHOLAS AINSLIE

Among the more important assignments during his 24 years of Governmental entomological service were investigations into the life history and control of the Spring grain—aphis or "Greenbug" in the central great plains area, 1907–1908; The New Mexico range caterpillar in the Southwest, 1908–1909; The alfalfa weevil in the Rocky Mountain region, 1910–1912; The Western grass-stem sawfly in the central great plains area, 1911–1918; The pale western cutworm in the Dakotas, 1918–1922. In addition to the various special assignments mentioned, his miscellaneous researches and his cooperation with other workers resulted in many valuable additions to the solution of other important problems, such as Hessian fly, chinch bug, grasshoppers, and numerous other cereal and forage pests. In performance of these duties, it was not only necessary for him to travel widely, but in a number of instances to spend considerable periods of time in remote areas of the country carrying out long-continued exacting investigational work under highly varied and often difficult and trying conditions. Practically no previous work had been done on the life history or control of some of these insects, notably the range caterpillar and alfalfa weevil which were recently discovered pests in this country, and it was necessary for him to secure much basic fundamental information. This was done by him with a thoroughness that has won the envy and the admiration of those who followed after and continued the studies of which his work formed the foundation. The various locations at which he had official headquarters during these years, to mention only those at which he had longest residence, included Washington, D. C., Salt Lake City, Utah, Elk Point, South Dakota, and Sioux City, Iowa. Upon reaching statutory retirement age, he was granted two extensions of service of two years each due to special qualifications for continuation of certain phases of the work. Upon retirement, October 31, 1930, he was continued as a Bureau collaborator.

In addition to specialization on insects attacking the cereal and forage crops, he was also deeply interested in the ecological relationships of birds and insects, and in the taxonomy and biology of certain of the Hymenoptera of economic importance. A natural bent for the study of insects led to the accumulation by him from year to year of a steadily growing and quite valuable collection of insects. In his later years after retirement the greater part of this was worked over by him and the more valuable material presented to the University of Minnesota and to the United States National Museum. It was also during this period that he prepared and issued, in a small edition for limited distribution, an autobiography dealing mainly with his early and middle life and distinctly anecdotal in scope. To this little book acknowledgment is gladly made for a portion of the data here presented. Even a cursory survey

of his published papers furnishes abundant evidence of the high character and thoroughness of his work and the wide range of his interests. He was a fellow of the American Association for the Advancement of Science, a member of the American Association of Economic Entomologists, Entomological Society of America, the Wilson Ornithological Club, and the Entomological Society of Washington.

His record is that of performance of work of great practical usefulness in a comparatively obscure field. In this he developed an enthusiasm which was sufficiently contagious to influence his oldest son, George, upon reaching maturity, to take up economic entomology as a life work. (JOUR. ECON. ENTO. 24(2): 567–569, port., 1931.) Mr. Ainslie had many sterling qualities, high ideals, positive convictions and a strongly marked individuality. Sensitive to the touch of beauty, he was a life-long student of flowers; a devoted lover of books, he formed an increasingly valuable and steadily growing library; an enthusiastic musician, he was for over 26 years the leader of a choir in the Congregational Church of Rochester and for "many years" was a member of the Rochester Symphony Orchestra. He possessed much personal charm and a most enviable gift for making and keeping friends. There are many of these to mourn his passing. In it, his friends and economic entomology have sustained a very real and genuine loss.—1-13-40. C. M. PACKARD
J. S. WADE

# CURRENT NOTES

## SOUTH TO CELEBRATE

THE fifth annual Florida Entomological Conference, will be held in Gainesville, Florida, on March 22 and 23.

The 1940 Conference will be in the nature of a celebration commemorating the 50th anniversary of the teaching of entomology in the South. The banquet on March 22 will be given in honor of Dr. H. A. Morgan, the pioneer teacher of entomology in the South.

Other leading American entomologists who are expected to attend are: Dr. Harry S. Smith, President of The American Association of Economic Entomologists, Dr. Arthur Gibson, Chief of the Dominion Division of Entomology of Canada, and Dr. Lee A. Strong, Chief of the Bureau of Entomology and Plant Quarantine.

## NORTH CENTRAL STATES CONFERENCES

THE nineteenth annual conference of the entomologists of the North-Central States will be held on March 21 and 22, 1940, in Lafayette, Indiana.

Following the usual plan of this group, there will be no prepared papers but a series of informal conferences on timely topics.

THE Central States Plant Board will meet on March 20, 1940. The meeting will precede the conference of the Entomologists.

A SPECIAL conference on the present status of Grasshopper Research has been called for March 23, 1940. This conference is to be held in Lafayette, Indiana, and follows other meetings scheduled for the same week. Dr. C. M. Packard, of the Bureau of Entomology and Plant Quarantine will be in charge.

## ANTIDOTES FOR POISONS

At the joint session of the Eastern Branch and the National Pest Control Association in New York, on November 16, 1939, Mr. George E. Sanders stressed the need for a good, up-to-date list of antidotes for the various toxic materials used by entomologists, and called attention to the recently compiled list by John Opitz and himself. This is available free from John Opitz, 50-14 Thirty-ninth St., Long Island City, N. Y. Mr. Sanders would welcome additions to this list and criticisms and suggestions from entomologists, toxicologists, physicians, druggists, and other interested parties.

## HUGO KOBLENZER DIES

Word has been received of the death, last November, of Hugo Koblenzer, an official of Standard Chemical Products Inc., and Standard Agricultural Chemicals, Inc., both of Hoboken, New Jersey. His residence was in North Bergen, N. J.

Mr. Koblenzer was born in Constance, Germany, and came to America at an early age. He resided in Chicago and became a citizen when he reached the age of 21 years. He studied at the University of Chicago and in Cornell University.

Mr. Koblenzer organized the New Brunswick Chemical Co., in New Jersey, in 1908 and continued with that company until 1920. He then went to Europe where he remained until 1925, having been associated during that period with chemical industries in several European countries.

Upon his return to America in 1925 Mr. Koblenzer formed the association with the companies with which he was connected at the time of his death.

Mr. Koblenzer was widely traveled and well known in the chemical industry all over the world. His acquaintance included many entomologists on account of his interest in insecticides.

Mr. Koblenzer was 59 years old at the time of his death. He is survived only by a daughter, Mrs. Johanna Koblenzer Klein.

## WHITMAN JOINS AGICIDE LABORATORIES

Mr. R. C. Whitman, for the last ten years with the Monsanto Chemical Company of St. Louis, has resigned and has joined Agicide Laboratories of Milwaukee and Los Angeles.

Mr. Whitman has been active in the development of wetting agents and detergents. He will be a member of the technical staff of Agicide Laboratories and will serve as Eastern District Manager for the company. Mr. Whitman may be addressed at 154 Watchung Ave., Chetham, N.J.

## NEW JERSEY MOSQUITO CONFERENCE

The dates of the annual conference of the New Jersey Mosquito Extermination Association have been announced as March 20, 21 and 22. The conference will be held at Atlantic City and the headquarters will be in the Hotel Haddon Hall.

Entomologists and other friends of the Association are invited to attend. Dr. Thomas J. Headlee, of the New Jersey Agricultural Experiment Station, is secretary of the Association.

## A. L. DUGAS GOES TO LOUISIANA

Mr. A. L. Dugas, a graduate of Louisiana State University and a recent graduate student in Iowa State College has been appointed to the staff of the Department of Entomology of the Louisiana Agricultural Experiment Station where his work will include studies of the insect pests of sugarcane.

## INDIANA PEST CONTROL OPERATORS ORGANIZE

Meeting in special session at the Purdue Memorial Union, Lafayette, Indiana, January 17, Indiana Pest Control Operators attending the Fourth Annual Purdue Pest Control Operator's Conference, decided to organize a state association and elected officers as follows: President, J. R. Franklin, of Hammond; Vice-President, E. E. Edwards, of Indianapolis; Secretary-Treasurer, C. O. Partlow, of Lafayette, and as Directors, Maurice Baillie, South Bend, Bert Lewis, Muncie, and J. E. Nicholas, Indianapolis. Dr. J. J. Davis, of Purdue University, acted as temporary chairman of the organization meeting.

At the next meeting, scheduled to be held at Purdue University March 22, constitution and by-laws will be formulated.

## CONFERENCE OF ENTOMOLOGISTS OF MAINE AND THE CANADIAN MARITIME PROVINCES

A conference of entomologists of Maine and the Canadian Maritime Provinces was held at the University of Maine, Orono, on January 17 and 18, 1940.

After a word of greeting from Dr. Fred Griffee, Director of the Maine Agricultural Experiment Station, the conference was opened with a brief address of welcome by Dr. Arthur A. Hauck, President of the University of Maine. On the afternoon of January 17 an informal reception was held at the home of President and Mrs. Hauck.

At noon on January 18, Mr. A. D. Pickett addressed the University of Maine Agricultural Seminar on the subject of "Problems and Practices in Apple Production in the Maritime Provinces."

The program of the conference consisted of informal presentation and discussion of problems concerning field crop insects, truck crop insects, forest and shade tree insects, and orchard and small fruit insects. At the final session it was decided to make such a conference an annual event.

Those attending the conference included: Jean C. Burnham, Dominion Plant Pathological Laboratory, Fredericton, New Brunswick; R. P. Gorham, C. W. B. Maxwell, W. A. Reeks, Dominion Entomological Laboratory, Fredericton, New Brunswick; A. E. McCollom, Dominion Plant Inspection Service, Saint John, New Brunswick; J. MacBain Cameron, Nova Scotia Department of Agriculture, Truro, Nova Scotia; A. D. Pickett, Dominion Entomological Laboratory, Annapolis Royal, Nova Scotia; A. E. Brower, A. L. Jones, R. W. Nash, H. B. Peirson, Maine State Forest Service, Augusta, Maine; Reiner Bonde, C. O. Dirks, Paul Gorham, Donald Folsom, J. H. Hawkins, F. H. Lathrop, I. C. Mason, Edith M. Patch, G. W. Simpson, F. H. Steinmetz, University of Maine, Orono, Maine.

## COTTON STATES BRANCH MEETING

The announcement and program of the meeting of the Cotton States Branch on February 7, 8 and 9 has just been received. These meetings will have been held before the JOURNAL reaches the readers.

The meetings are scheduled to be held in Birmingham, Alabama, with headquarters in the Bankhead Hotel.

A very attractive program which fittingly recognizes the Fiftieth Anniversary Year of the Association has been issued and many interesting papers are to be presented.

The officers in charge of the meetings are Oliver I. Snapp, Chairman; L. L. English, Vice-Chairman and John T. Creighton, Secretary.

Photographs of twelve entomologists who have been particularly active in entomology in the South are attractively reproduced in the printed program. The entomologists so honored include the late Dr. W. E. Hinds, Franklin Sherman, G. M. Bentley, J. M. Robinson, R. W. Harned, the late Dr. J. W. Folsom, R. W. Leiby, S. W. Bilsing, Clay Lyle, W. E. Anderson, C. O. Eddy and the Chairman, O. I. Snapp.

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# HORTICULTURAL INSPECTION NOTES

A CONFERENCE to discuss control of the pink bollworm of cotton in the United States, called by Dr. Lee A. Strong, Chief of the Bureau of Entomology and Plant Quarantine, was held at San Antonio, Tex., on December 15, 1939. The meeting was attended by a large number of pest-control workers and representatives of the cotton industry and of related commercial organizations. A full report on the present status of the pink bollworm in the United States and the progress of control and eradication activities was presented. Much interest was shown by those in attendance, who urged that Federal and State regulatory and suppressive activities be continued.

GENERAL headquarters of the grasshopper control project of the Bureau of Entomology and Plant Quarantine were moved from Minneapolis to Denver the first of the year, with office space at the Insurance Exchange Building, 810 14th Street. A district headquarters will be maintained at Minneapolis. The grasshopper control project of the Division of Domestic Quarantines, under the leadership of B. M. Gaddis, will be under the Field Directorship of Dr. Claude Wakeland, who also acts in a similar capacity over the Salt Lake City headquarters for Mormon cricket control. Dr. W. E. Dove, who has had charge of the grasshopper control project, has been transferred at his own request to research activities with the Division of Insects Affecting Man and Animals.

# PROCEEDINGS OF THE FIFTIETH ANNIVERSARY MEETING

## AMERICAN ASSOCIATION OF ECONOMIC ENTOMOLOGY

### Deshler-Wallick Hotel, Columbus, Ohio, December 27–30, 1939

Dr. Neale F. Howard and his very competent committee arranged for the meetings of the American Association of Economic Entomologists and the Entomological Society of America at Columbus, December 27–30 at the Deshler-Wallick Hotel. This meeting was the 50th anniversary meeting of the founding of the American Association of Economic Entomologists, and the celebration was participated in by both organizations with about 500 entomologists in attendance, 352 of whom registered with this Association.

Of the seven living charter members, only one was present, Dr. Herbert Osborn, Professor Emeritus of the Ohio State University, who presided at the joint session, a Symposium on Fifty Years of Economic Entomology. Five speakers took up the history and accomplishments of the organization, beginning with 1889 when it was organized at Toronto, Ontario, and continuing to the present time. These speakers were: Dr. C. L. Marlatt, former Chief of the Bureau of Entomology and Plant Quarantine, Washington, D. C.: Professor Lawson Caesar, Professor of Entomology, Ontario Agricultural College, Guelph, Ontario; Dr. C. L. Metcalf, Professor of Entomology, University of Illinois, Urbana, Illinois; Professor E. O. Essig, Professor of Entomology, University of California, Berkeley, California; and Mr. S. A. Rohwer, Assistant Chief, Bureau of Entomology and Plant Quarantine, Washington, D. C. The speakers dealt with early efforts at insect control, such as the importation from Australia of the Vedalia ladybird to feed upon the cottony cushion scale through the work of Albert Koebele in 1889, to present day large-scale insect control undertakings.

A pleasant surprise during the joint session was a message of greeting from Dr. L. O. Howard, one of the organizers, who was unable to attend the meeting, but whose message was brought over long distance telephone and amplified through a loud speaker.

Dr. Howard's message was followed by the Presidential Address, "Undesirable Insect Aliens" by E. R. Sasscer, of the Bureau of Entomology and Plant Quarantine.

The Public Address of the Entomological Society of America given by Dr. A. Avinoff, Director of the Carnegie Museum, Pittsburgh, Pa., who discussed "Designs and Patterns in the Lepidoptera and Other Animals," was attended by more than 400.

One hundred and seven papers were presented in the program of the Economic Entomologists. Four rooms were devoted to exhibits covering the field of insect biology and control. The Section of Plant Quarantine and Inspection held a joint meeting with the American Phytopathological Society for a Symposium on "Viruses and Plant Quarantines" and the Section of Teaching presented a Symposium on "Training for Various Fields of Entomology."

The Entomologist's Dinner was attended by 305 and proved to be a very enjoyable affair. Several skits presented by local entomologists were well received, especially the Monologue by "Farmer" Cutright. Dr. Harlan Worthley sang several songs and was recalled for encores. Professor C. C. Weidemann of Ohio State University, after presenting many musical oddities, trained Messrs. Herms, Davis, Hoyt, Phillips and Horsfall to play the baby grand marimba and had them accompany him in two numbers.

The local committee of D. M. DeLong, F. L. Campbell, T. S. Parks, J. S. Houser, Alvah Peterson, R. A. Fulton, J. N. Knull and Harold Waters with Neale F. Howard as Chairman, handled every detail in the most efficient and satisfactory manner and were assisted in their work by graduate and undergraduate students from the Department of Entomology and Zoology of the Ohio State University.

## REPORT OF THE SECRETARY AND BUSINESS MANAGER

The routine work of this office has assumed about the same pattern and proportions as in the past several years. The percentage of those in arrears has been reduced by the definite policy adopted last year in regard to arrearage in dues. In some instances, past records have been found to be inadequate and such cases have been settled on the most liberal possible terms.

There is now an active list in good standing of 1,096; an unchanged honorary list of 39; members with dues remitted 10; life members (2 added in 1939) 8; reinstatements 15; resignations 13; deaths 11; members whose mail has been returned 32; members dropped for arrearage of more than two years, 32; active members in arrears for 1938 and 1939, 36.

All active members in arrears for 1938 and 1939 have had their delinquencies called to their attention, and I am confident will have paid before this report is read. We have a total membership of 1,224, to which will be added 161 members elected at the final session.

The large number of applications is largely the direct result of the active campaigning of several members and leads me to the proposal that the Membership Committee be enlarged by the addition of two members, at least one of whom should be a representative of the Bureau of Entomology and Plant Quarantine from the southern states, and the others, including the present members, should be so distributed geographically that every section of the country will be represented.

Another proposal that deserves consideration is the redefinition of the functions of the Committee on Popular Entomological Education. The present committee has done a splendid piece of work in the collection of data annually in regard to the scope and amount of information carried by publications in regard to entomology, and this function should be continued. In addition, however, we should have an active and continuous attempt made to publicize not only entomology but those who are making entomological contributions of note and in regard to this Association. We need to advise the public constantly of the who, when, what, where activities of our members. I, therefore, suggest that the Executive Committee advise the Committee on Popular Entomological Education of this new concept of their function and that the membership at large be urged to cooperate. It would also be desirable to coordinate the functions of local committees on publicity with this committee and thereby achieve continuity of policy.

The advertising situation has been discussed at length in the Executive and Publications Committees at various times, but I think the membership at large has not been fully apprised of the many considerations that should govern the policy in regard to advertising. The employment of an individual or an agency to secure advertising has been suggested, but each time the Executive Committee has ruled against this procedure because the success of such a campaign rests upon profits to the individual or agency and they in turn must rest upon high pressure salesmanship, which would undoubtedly lead, some time, to embarrassment for the Association. A limited return from advertisements is vastly better than a large income from advertisements, one of which might backfire. Therefore, the Executive Committees have ruled that the Business Manager must be responsible for all advertising. This does not mean that help from the membership is not needed and the appointment, last year, of an informal committee to assist is a worthwhile endeavor.

Thought should be taken in regard to the publication of INDEX VI. A fund is being set up from the membership fees for this purpose. Many questions had to be settled as to scope, format, etc. just before the editing of INDEX V began that should be settled now for Index VI, and if possible the editor should be selected so that the publication will move forward in an orderly manner. The next index should be assembled in 1940. It might be well to point out that, while the Index V account is carried as a deficit, actually all bills have been paid and ultimately Index V should show a profit as have the others. In last year's audit, the honorarium paid Dr. Felt was included in editorial costs which has created confusion in the minds of some. The editor of the JOURNAL has never received more than $200.00, and in my judgement this honorarium should be substantially increased.

This brings to mind the subject of future policy in regard to the editorial work, about which no doubt the Publications Committee will have specific recommendations. But, since the question of the employment of a full-time editor or a combination editor-business manager has been the subject of several widely distributed communications, I believe that I am justified in pointing out certain considerations that should have a bearing. While the JOURNAL now shows a healthy balance, no one can predict with assurance what the future may bring forth. We do, however, have the experience of the World War conditions of 20 years ago to serve as a guide. We are just now getting back to normal as far as memberships and dues are concerned, and the subscription lists were in a chaotic condition for many years. We have had some cancellations and should this country become involved or if present war conditions continue for several years, we would undoubtedly face lean years.

At the present time the Association is the recipient of free services, furniture and quarters, which would need to be replaced under any full-time arrangement. Unless full-time compensation amounted to an adequate living wage, sooner or later the incumbent would be forced to seek additional sources of income and then you would be right back where you started, with a part-time employee, at a much greater cost than at present.

Probably only a few of us know the time, thought, and energy that Dr. Frison has devoted to the task of putting the JOURNAL on its present high plane, scientifically and technically. It is doubtful whether any paid editor would have accomplished as much. His successor will have difficulty in excelling the work done, but an editor who can do just that is the only kind this Association can afford to select.

The Executive Committee has been considering a long-time schedule of meeting places and will present its conclusions on Friday. This is the most important business to come before the Association, and I am sure the Committee will welcome suggestions.

ERNEST N. CORY, *Secretary and Business Manager*

College Park, Md.
December 22, 1939

Dr. E. N. Cory, Secretary
American Association of Economic Entomologists
College Park, Maryland

Dear Dr. Cory:

I have supervised the examination of the accounts of the American Association of Economic Entomologists for the fiscal year ended November 15, 1939. The results of the examination are set forth in the exhibits and schedules designated as follows:

Exhibit "A" Balance Sheet, November 15, 1939.
Exhibit "B" Statement of Receipts and Disbursements.
Exhibit "C" Statement of the Permanent Fund, November 30, 1939.
Schedule 1 Statement Showing Adjustments from Cash to Accrual Basis.
Schedule 2 Subscriptions Receivable, Non-members.*
Schedule 3 Subscriptions and Dues Receivable, Members.*

The assets and liabilities as shown on Exhibit "A" are more fully described in the following paragraphs:

*Cash—$8,351.41:*
The above balance is represented by the following:

| | | |
|---|---|---|
| Prince Georges Bank & Trust Company, Hyattsville, Md.: | | |
| Savings Account (2%) | $ 963.76 | |
| Checking Account | 4,148.78 | $5,112.54 |
| Franklin County Trust Company, Greenfield, Mass.: | | |
| Savings Account (2½%) | | 1,166.38 |
| First National Bank of Amherst, Mass., Savings Acct. (1½%) | | 1,678.03 |
| Cash on Hand | | 394.46 |
| Total Cash | | $8,351.41 |

The bank balances at November 15, 1939 were verified by positive confirmations from the depositary banks, and the cash on hand was counted at the close of business on November 15, 1939.

*Unclipped, Matured Coupons—$133.74:*
These coupons were deposited in the permanent fund's savings account at the Prince Georges Bank & Trust Company on November 18, 1939.

*Accrued Interest Receivable—$108.64:*
As at November 15, 1939 interest had accrued on the following securities (This interest is not included in Exhibit "C," the statement of the Permanent Fund):

| | |
|---|---|
| Province of Ontario, 5's | $ 4.16 |
| U. S. Treasury Bonds, 3½'s | 6.77 |
| U. S. Treasury Bonds, 2½'s | 14.37 |
| U. S. Savings Bonds, Series A | 4.17 |
| U. S. Savings Bonds, Series D | 79.17 |
| Total Accrued Interest Receivable | $108.64 |

*Subscriptions Receivable—$837.80:*
The details of this balance are set forth on the following schedules:

| | | |
|---|---|---|
| Schedule 2 (non-members) | | $156.80 |
| Schedule 3 (members): | | |
| 1938 Subscriptions | $114.00 | |
| 1939 Subscriptions | 567.00 | 681.00 |
| Total Subscriptions Receivable | | $837.80 |

*Dues Receivable—$499.00:*
The details of this balance are also set forth on schedule 3 as follows:

| | |
|---|---|
| 1938 Dues | $ 85.00 |
| 1939 Dues | 414.00 |
| Total Dues Receivable | $499.00 |

*Reserve for Uncollectible Accounts—$133.68:*
A reserve of 10% of the outstanding receivables has been set up to cover accounts that may become uncollectible.

*Investments—$20,568.00:*
The details of these investments are set forth on Exhibit "A." All securities are carried at cost (book value) with the exception of the U. S. Savings Bonds which are carried at their redemption value as at November 15, 1939.

*Unexpired Insurance—$15.90:*
The above sum represents the unexpired premiums on the following policies:

| Policy No. | Description | Amount | Unexpired Premiums |
|---|---|---|---|
| 590166 | Surety bond for secretary | $5,000 | $ 4.02 |
| 558 | Fire Insurance on Books, Furniture and Equipment | 4,600 (Books) | |
| | | 100 (Furn.) | 11.88 |
| | | | $15.90 |

The back numbers of the JOURNAL OF ECONOMIC ENTOMOLOGY and Index V are kept at Menasha, Wisconsin, and are covered by a blanket policy taken out by the publishers.

*Inventories—$10,122.56:*
A physical inventory of the association's publications revealed the following:

| | Indices | | | | | |
|---|---|---|---|---|---|---|
| | I | II | III | IV | V | Total |
| No. of Copies | 222 | 575 | 270 | 547 | 664 | 2,284 |
| Unit Cost* | $ 1.50 | $ 1.50 | $ 1.50 | $ 1.50 | $ 2.04 | |
| Total Cost | $333.00 | $862.50 | $414.00 | $820.50 | $1,354.56 | $3,784.56 |

* These schedules change daily and therefore are not printed.—E. N. C.

Auditor's Statement, (*Con't.*)

| | |
|---|---|
| Total cost of Indices brought forward | $ 3,784.56 |
| JOURNAL OF ECONOMIC ENTOMOLOGY | |
| Number of copies—12,501—unit cost, 50¢* | $ 6,250.50 |
| COMMON NAMES OF INSECTS | |
| Number of copies—175—selling price, 50¢ | 87.50 |
| Total Inventory | $10,122.56 |

*Furniture and Equipment—$1.00:*
The furniture and equipment which consists of several filing cabinets has been given the nominal value of $1.00.

*Current Liabilities—$268.86:*
The details of the current liabilities are set forth on Exhibit "A." There are no fixed liabilities.

*Subscriptions and Dues Collected in Advance—$1,572.90:*
The above sum represents the subscriptions and dues collected for the year 1940, and therefore should not be taken into income until actually earned.

*Unearned Subscriptions and Dues—$1,407.15:*
Although the association takes up as income all subscriptions and dues collected, it has not actually earned these fees until the year for which they are paid has expired. The unearned subscriptions ($1,119.65) represents the association's liability to deliver the December issue of the JOURNAL to its subscribers (with few minor adjustments which have been made for subscriptions not coinciding with the calendar year), and the unearned dues ($287.50) represent payments for membership in the association for the year 1939 which will not expire until December 31.

*Net Worth—$37,255.46:*
The details of the net worth appear on Exhibit "A" while explanations for the balances shown thereon may be found on Schedule 1. Although Index VI has not as yet been published, 50¢ of all dues collected for the year 1939 and 1940 has been allocated to this index to help cover the cost of printing when the index is published in 1941.

In my opinion the accompanying statements and supporting schedules presents fairly the financial position of the American Association of Economic Entomologists at November 15, 1939.

Respectfully submitted,
(Signed) S. M. WEDEBERG
*Certified Public Accountant*

* Unit cost for indices I–IV unknown; estimate of $1.50 made by the business manager.
* Also estimated.

*Exhibit "A"*

## American Association of Economic Entomologists, Balance Sheet*

### As of November 15, 1939

ASSETS

| | | | | |
|---|---|---|---|---|
| *Current Assets:* | | | | |
| Cash | | | $8,351.41 | |
| Unclipped, Matured Coupons | | | 133.74 | |
| Accrued Interest Receivable | | | 108.64 | |
| Subscriptions Receivable: | | | | |
| Non-members | $156.80 | | | |
| Members | 681.00 | $ 837.80 | | |
| Dues Receivable | | 499.00 | | |
| Total Subscriptions & Dues Receivable | | $ 1,336.80 | | |
| Less Reserve for Uncollectible Accounts | | 133.68 | 1,203.12 | |
| Total Current Assets | | | | $ 9,796.91 |

*Investments:*

| PAR VALUE | DESCRIPTION | MARKET VALUE | BOOK VALUE | |
|---|---|---|---|---|
| $ 2,000 | Province of Ontario, 5's | $ 2,080.00 | $2,000.00 | |
| 2,500 | U. S. Treas. Bonds, 3¼'s | 2,731.25 | 2,484.00 | |
| 3,000 | U. S. Treas. Bonds, 2½'s | 3,174.00 | 2,984.00 | |
| 5,000 | U. S. Sav. Bonds, Series A | 4,100.00 | 4,100.00 | |
| 12,000 | U. S. Sav. Bonds, Series D | 9,000.00 | 9,000.00 | |
| $ 24,500 | | $21,085.25 | | $20,568.00 |

| | | |
|---|---|---|
| *Prepaid Expenses:* | | |
| Unexpired Insurance | | $ 15.90 |
| *Inventories:* | | |
| Inventory of Indices I–V | $3,784.56 | |
| Inv. of Back Nos. of the JOURNAL OF ECONOMIC ENTOMOLOGY | 6,250.50 | |
| Inventory of Common Names of Insects | 87.50 | $10,122.56 |
| *Fixed Assets:* | | |
| Furniture & Equipment | | 1.00 |
| *Total Assets* | | $40,504.37 |

* NOTE: Since the funds of the branches have not been audited, they are not included in the balance sheet.

LIABILITIES AND NET WORTH

| | | | |
|---|---|---|---|
| *Current Liabilities:* | | | |
| Accounts Payable | | $ 18.86 | |
| Due to Editor | | 100.00 | |
| Due to Assistant Editor | | 150.00 | |
| Total Current Liabilities | | | $ 268.86 |
| *Deferred Credits:* | | | |
| Subscriptions Collected for the Year, 1940 | $ 973.90 | | |
| Dues Collected for the year, 1940 | 399.00 | | |
| Total Subscriptions & Dues Collected in Advance | | $ 1,372.90 | |
| Unearned Subscriptions | $1,119.65 | | |
| Unearned Dues | 287.50 | | |
| Total Unearned Subscriptions & Dues | | $ 1,407.15 | |
| Total Deferred Credits | | | $ 2,980.05 |
| *Net Worth:* | | | |
| JOURNAL | | $ 9,279.71 | |
| Association | | 3,735.70 | |
| Indices I–IV | | 3,775.56 | |
| Index V | | 1,321.35* | |
| Index VI | | 345.32 | |
| Permanent Fund | | 21,440.52 | |
| Total Net Worth | | | $37,255.46 |
| Total Liabilities and Net Worth | | | $40,504.37 |

*Exhibit "B"*

## American Association of Economic Entomologists, Statement of Cash Receipts and Disbursements

### For the Fiscal Year Ended November 15, 1939

| | TOTAL | JOURNAL | ASSOCIATION | INDICES I–IV | INDEX V | INDEX VI |
|---|---|---|---|---|---|---|
| *Receipts:* | | | | | | |
| Subscriptions | $ 6,037.19 | $ 6,037.19 | | | | |
| Advertising | 108.39 | 108.39 | | | | |
| Reprints | 1,783.08 | 1,783.08 | | | | |
| Back numbers | 165.27 | 165.27 | | | | |
| Dues | 2,161.15 | | $1,687.36 | | | $ 473.79 |
| Sales | 241.05 | | | $ 94.45 | $ 146.60 | |
| Interest on bank deposits | 24.89 | | 24.89 | | | |
| Miscellaneous | 200.53 | 180.03 | 20.50 | | | |
| Total Receipts | $10,721.55 | $ 8,273.96 | $1,732.75 | $ 94.45 | $ 146.60 | $ 473.79 |
| *Balance*, November 15, 1938 | 8,102.32 | 4,790.67 | 4,865.22 | 1,252.58 | 2,806.15* | |
| | $18,823.87 | $13,064.63 | $6,597.97 | $1,347.03 | $2,659.55* | $ 473.79 |
| *Disbursements:* | | | | | | |
| Audit, period ended Nov. 15, 1938 | $ 35.00 | | $ 35.00 | | | |
| Accounting services | 23.50 | $ 11.75 | 11.75 | | | |
| Surety bond for secretary | 12.50 | | 12.50 | | | |
| Printing | 6,660.72 | 6,421.14 | 239.58 | | | |
| Engravings, drafting, etc. | 652.08 | 652.08 | | | | |
| Editor's salary | 200.00 | 200.00 | | | | |
| Assistant editor's salary | 300.00 | 300.00 | | | | |
| Salary, secretary & bus. manager | 600.00 | 300.00 | 300.00 | | | |
| Stenographer to editor | 92.00 | 92.00 | | | | |
| Stenographer to secretary | 114.75 | 36.60 | 78.15 | | | |
| Clerical work | 142.71 | 67.66 | 75.05 | | | |
| Traveling expenses: E. N. Cory | 59.91 | | 59.91 | | | |
| J. J. Davis | 349.56 | | 349.56 | | | |
| Convention expenses | 29.05 | | 29.05 | | | |
| Branch expenses: Pacific Slope | 75.63 | | 75.63 | | | |
| Cotton States | 52.05 | | 52.05 | | | |
| Postage, stationery & supplies | 597.43 | 322.75 | 268.50 | | $ 6.18 | |
| Telephone & telegraph | 23.06 | 4.95 | 18.11 | | | |
| Express | 12.82 | 1.17 | | $ 1.47 | 10.18 | |
| Service charges | 3.68 | 1.84 | 1.84 | | | |
| Refunds | 46.90 | 29.90 | 17.00 | | | |
| Miscellaneous | 19.25 | | 19.25 | | | |
| Transfer to permanent fund | 1,000.00 | | 1,000.00 | | | |
| Total Disbursements | $11,102.60 | $ 8,441.84 | $2,642.93 | $ 1.47 | $ 16.36 | |
| *Balance*, November 15, 1939 | $ 7,721.27 | $ 4,622.79 | $3,955.04 | $1,345.56 | $2,675.91* | $ 473.79 |

| | |
|---|---|
| The balance is represented by the following: | |
| Prince Georges Bank & Trust Company, Hyattsville, Md. (checking account) | $4,148.78 |
| First National Bank of Amherst, Mass. (savings account at 1½%) | 1,678.03 |
| Cash on hand | 394.46 |
| U. S. Savings Bonds, Series D | 1,500.00 |
| Balance, November 15, 1939 (as above) | $7,721.27 |

* Debit balance.

*Exhibit "C"*

## American Association of Economic Entomologists, Statement of the Permanent Fund

### For the Period from November 30, 1938 to November 30, 1939

| | | | |
|---|---|---|---|
| *Balance*, November 30, 1938, as per previous report | | | $19,759.08 |
| *Income for the period:* | | | |
| Interest received from securities | | $267.50 | |
| Interest from savings deposits: | | | |
| Prince Georges Bank & Trust Co. | $76.70 | | |
| Franklin County Trust Co. | 28.60 | 105.30 | |
| Interest credited to book value of U. S. Savings Bonds | | 100.00 | |
| Life Membership received | | 100.00 | |
| Total income for the period | | | 572.80 |
| Transferred from Association Funds | | | 1,000.00 |
| *Balance*, November 30, 1939 | | | $21,331.88 |

The balance is invested as follows:

| Par Value | Securities | Market Value Nov. 30, 1939 | Book Value | |
|---|---|---|---|---|
| $ 2,000 | Province of Ontario, 5's | $ 2,075.00 | $2,000.00 | |
| 2,500 | U. S. Treasury Bonds, 3½'s | 2,732.25 | 2,484.00 | |
| 3,000 | U. S. Treasury Bonds, 2¼'s | 3,185.40 | 2,984.00 | |
| 5,000 | U. S. Savings Bonds, Series A | 4,100.00 | 4,100.00 | |
| 10,000 | U. S. Savings Bonds, Series D | 7,500.00 | 7,500.00 | |
| $22,500 | | $19,592.65 | | $19,068.00 |
| | Bank Deposits (Savings Accounts) | | | |
| Prince Georges Bank and Trust Co., Hyattsville, Md. (Interest Rate, 2%) | | | $1,097.50 | |
| Franklin County Trust Co., Greenfield, Mass. (Interest Rate, 2½%) | | | 1,166.38 | 2,263.88 |
| *Balance of investments* (as above) | | | | $21,331.88 |

*Schedule 1*

## American Association of Economic Entomologists, Statement Showing Adjustments from Cash to Accrual Basis

| | Journal | Association | Indices I–IV | Index V | Index VI | Permanent Fund | Total |
|---|---|---|---|---|---|---|---|
| 1. Per Exhibits "B" & "C" | $4,622.79 | $3,955.04 | $1,345.56 | $2,675.91* | $473.79 | $21,331.88 | $29,053.15 |
| Accrued Interest Receivable | | | | | | 108.64 | 108.64 |
| Subscriptions Receivable | 837.80 | | | | | | 837.80 |
| Dues Receivable | | 395.50 | | | 103.50 | | 499.00 |
| Unexpired Insurance | | 15.90 | | | | | 15.90 |
| Inventories | 6,250.50 | 87.50 | 2,430.00 | 1,354.56 | | | 10,122.56 |
| Furniture & Equipment | | 1.00 | | | | | 1.00 |
| | $11,711.09 | $4,454.94 | $3,775.56 | $1,321.35* | $577.29 | $21,440.52 | $40,738.05 |
| Subtract: | | | | | | | |
| Reserve for Uncollectible Accounts | $ 83.78 | $ 39.55 | | | $ 10.35 | | $ 133.68 |
| Accounts Payable | 254.05 | 14.81 | | | | | 268.86 |
| Subscriptions, 1940 | 973.90 | | | | | | 973.90 |
| Dues, 1940 | | 449.25 | | | 149.75 | | 599.00 |
| Unearned Subscriptions | 1,119.65 | | | | | | 1,119.65 |
| Unearned Dues | | 215.63 | | | 71.87 | | 287.50 |
| | $2,431.38 | $ 719.24 | | | $231.97 | | $ 3,382.59 |
| *Net Worth, Exhibit "A"* | $9,279.71 | $3,735.70 | $3,775.56 | $1,321.35* | $345.32 | $21,440.52 | $37,255.46 |

* Debit balance.

## Report of the Section of Plant Quarantine and Inspection

The meeting of the Section was called to order at approximately 9 o'clock a.m., in the Deshler-Wallick Hotel, by the Chairman, Mr. G. T. French. The morning session was held jointly with the American Phytopathological Society, and papers and discussions relating to viruses and plant quarantines, were presented by Messrs. Freeman Weiss, K. Starr Chester, L. D. Christenson, and Howard P. Barss. All papers presented were of a very constructive nature, and at the conclusion of the presentations there were active and constructive comments from the floor.

At the afternoon meeting an address was given by the Chairman on the subject, "Standardization and uniformity in Plant Quarantine and Control Procedure," followed by papers by Mr. Avery S. Hoyt and Dr. Wilmon Newell on the subject of "Federal-State Relations." Presentations were followed by a general discussion into which those in attendance entered in an active and constructive manner.

The attendance at the morning and afternoon sessions was greater than at any meeting of the section in recent years.

The discussions were followed by a short business meeting. The Nomination Committee, of which Dr. A. B. Buchholz was Chairman, proposed the nomination of Dr. G. S. Langford as Chairman and Mr. R. G. Richmond as Secretary. The report was unanimously approved.

The Resolutions Committee, of which Mr. F. L. Guyton was Chairman, submitted the following resolutions which were unanimously adopted.

*Whereas*, the joint session of the American Phytopathological Society and the Section of Plant Quarantine of the American Association of Economic Entomologsts has been very beneficial, and;

*Whereas*, the members present have been highly profited by the presentation of these papers and the discussion which followed,

*Be it Resolved*, that the individuals participating in today's program be thanked for their efforts in presenting this subject of virus diseases and plant quarantines and that our officers be requested to continue to arrange such joint sessions at future meetings, and; that, inasmuch as it was possible for the papers presented at the joint meeting held in Richmond in 1938 to be mimeographed and distributed by the Bureau of Entomology and Plant Quarantine prior to their publication in the JOURNAL and that inasmuch as such early publication was valuable and highly appreciated, be it further resolved, that our officers do what they can to secure as early publication of the papers presented at this meeting as possible, and:

That, be it further resolved, that this session herewith express our thanks to our local commitee for the splendid arrangements they have provided for this meeting.

ROY G. RICHMOND, *Secretary*

## REPORT OF THE SECTION OF APICULTURE

The Section of Apiculture, with Chairman W. E. Dunham presiding, met at 9:30, December 27, in Room 218 of the Deshler-Wallick. Seven of the ten topics listed on the program were presented; three, due to the absence of the authors were read by title only. After a vote by the Section to have it presented, one title received too late to be included in the printed program was discussed.

At the conclusion of the program, the report of the Nominating Committee was received. This resulted in the election of Frank R. Shaw, Amherst, Mass., Chairman, and W. A. Price, Lexington, Ky., Secretary for the coming year.

W. A. PRICE, *Secretary*

## REPORT OF THE SECTION OF EXTENSION

The eleventh annual meeting of the Section on Extension met on Thursday, afternoon, December 28, in Room 216 of the Deshler-Wallick, with Chairman George D. Jones of Missouri, presiding. The program was built around the theme of the effects of present day agricultural practices on insect problems. The two main papers were presented by J. L. Boatman, Washington, D. C., on "Subject Matter Programs in Relation to Present Day Agriculture," and in the absence of Dr. P. N. Annand, Washington, D. C., his paper on "Recent Changes in Agriculture and their effects on Insect Problems" was presented by S. A. Rohwer of Washington, D. C. Nine other speakers discussed topics directly related to the two main papers, which brought out a lively discussion from the floor. Professor Dean of Kansas summarized the present day agricultural practices and their relation to insect problems in that state in a most interesting way. He brought out the fact that the subject of entomology plays a very important role in practically all agricultural practices and should not be overlooked.

The officers elected for the ensuing year are: Chairman, C. B. Dibble, and Secretary, G. E. Lehker.

J. O. PEPPER, *Secretary*

## REPORT OF THE SECTION OF TEACHING

The first annual meeting of the Section of Teaching was called to order at 7.30 p.m., December 29, in Parlors A, B, and C of the Deshler-Wallick, by the chairman, John T. Creighton. Some 250 entomologists were present. This large number necessitated the holding of the meeting in Parlors A, B and C instead of in room 216 as originally scheduled.

The program consisted of an address by the Chairman, "Entomological Instruction, Past, Present and Future," and a Symposium on Training for the Various Fields of Entomology. The following contributed papers to the symposium: P. N. Annand, Bureau of Entomology and Plant Quarantine, "Training for Research," whose paper was read by S. A. Rohwer; M. P. Jones, Extension Entomologist, U. S. Department of Agriculture, "Training for Extension"; Harlow B. Mills, Montana State College, "Training for Teaching"; Avery S. Hoyt, Bureau of Entomology and Plant Quarantine, "Training for Plant Quarantine and Control Work"; and J. J. Davis, Purdue University, "Training for Pest Control and Commercial Work in Entomology."

Thirty-three entomologists attended the dinner honoring the early teachers of entomology, which was held in the Southern Hotel preceding the meeting. The following teachers of entomology were introduced at this dinner: L. M. Peairs, W. B. Herms, J. J. Davis, W. P. Hayes, E. O. Essig, S. W. Bilsing, C. L. Fluke, and D. M. DeLong.

Some 17 schools participated in the excellent exhibits of teaching methods and technique which was sponsored by the section.

Dr. C. L. Metcalf of the University of Illinois was elected chairman and Dr. Roger C. Smith of the Kansas State College of Agriculture and Applied Science was elected secretary for the year 1940.

HOWARD O. DEAY, *Secretary*

## REPORT OF THE TRUSTEE FOR THE TROPICAL PLANT RESEARCH FOUNDATION

Your representative on the Tropical Research Foundation can report for the past year that while no projects were under way the affairs of the Foundation have been cared for with the usual efficiency of Dr. William Crocker who is serving as Acting Director. From his recent reports I can report that a readjustment of expenses for the management of the funds will result in a larger income and the continuation of the same management as in recent years. It is possible, however, that some arrangement may be made with some organization in a position to administer funds on a permanent basis.

It appears to be the judgment of a majority of the Trustees that such an arrangement be held in abeyance for further consideration. I have received from Dr. Crocker detailed financial statement which may be of interest to the Association and can be published if that is desired. In brief, it indicates assets of about $77,000, with an income of approximately $1,500 last year and a probable annual income of from $1,500 to $1,800 in future years. Ultimately it should be possible to finance some studies of interest to entomologists as well as other biologists, or to place the fund where it can be of distinct service in tropical research. A possible avenue for some such service may be found in connection with the Tropical Forest Experiment Station in Puerto Rico, and it is a matter of interest that this station is issuing a quarterly Journal under the name of *The Caribbean Forester*.

Respectfully submitted,
HERBERT OSBORN, *Trustee*

FINANCIAL STATEMENT

TROPICAL PLANT RESEARCH FOUNDATION

December 4, 1939

| | *Debit* | *Credit* |
|---|---|---|
| Capital invested in property | | $70,805.99 |
| Various buildings, equipment, etc. | $70,805.99 | |
| Washington Office | | 3,138.96 |
| Soils of Cuba | 880.64 | |
| Supplements, etc. | 144.75 | |
| Kingdom of Norway Bonds (par $4,000) | 4,110.00 | |
| Interest | | 2,223.37 |
| Tropical Forests Caribbean | | 944.38 |
| Cuba Sugar Club | | 316.90 |
| Cash | 1,488.22 | |
| | $77,429.60 | $77,429.60 |

*Receipts and Disbursements*

June 22, 1938–December 4, 1939

| | | |
|---|---|---|
| Balance at beginning of period | | $ 400.48 |
| Sales, Soils of Cuba | | 147.57 |
| Sales, Tropical Forests | | 21.00 |
| Sales of supplements and miscellaneous | | 5.18 |
| Interest received on bonds | | 450.00 |
| Principal received on bonds | | 1,000.00 |
| | | $ 2,024.23 |
| Treasurer's salary | $ 400.00 | |
| Treasurer's bond | 6.25 | |
| Safe deposit box | 6.60 | |
| Boyce Thompson | 63.16 | |
| Refund on interest on bond | 60.00 | |
| *Balance*, December 4, 1939 | | $ 1,488.22 |

## REPORT OF THE REPRESENTATIVE ON THE NATIONAL RESEARCH COUNCIL

The Division of Biology and Agriculture of the National Research Council during the past year has dealt with many different subjects. Your representative has attended and participated in the regular meetings of the division and as a member of committees has been associated with certain of its activities. Not all of the matters considered by the Division have an immediate or direct bearing on the activities of our Association. The report mentions only certain matters which have come before this Division of the Research Council that may be of immediate interest to members of the Association.

The Committee on Forestry of the Division of Biology and Agriculture has completed and given limited circulation to a mimeographed report on a survey of forest research in the United States. It has completed in manuscript form a bibliography of forestry down to 1933. It is understood that these include references to insect pests and that the Division or the Chairman of the Committee will furnish further information to those who may be interested. The Committee on Forestry is now assembling information about tree seeds. Their study covers a broad field, including not only the use of seeds but also matters pertaining to their certification.

The Division's Committee on Research Publications has been active along a number of lines. Studies are being made as to the possibility of making better provision for the dissemination of research information and changes of style and format which may effect economy in publication. They are exploring the desirability of scientific publications adjusting subscription prices so universities, scientific and public institutions will give more support to the disseminating of results of research by paying even higher subscription rates for technical publications.

The Division's Committee on the Ecology of Grasslands has considered a number of matters. One of these was submitted by the United States Department of Interior, requesting the Research Council to comment on a suggestion that a Great Plains National Monument be established in which a large grassland area would be set aside, maintained in its natural condition, and be available for research observations. The report prepared discussed this question from various points of view. Should any large grassland area be set aside and maintained for these or other purposes, it would be of interest to entomologists. Those studying insects associated with natural grassland areas will find the various activities in this field and the work of this Committee of interest.

The Division of Biology and Agriculture and later the National Academy endorsed a recommendation of the special committee appointed the previous year to consider ways of relieving the somewhat precarious financial status of Barro Colorado Island, the only tropical station for biological research under the American flag and one which has had such a distinguished career in biological research. The special Committee suggested that Congress be asked to pass legislation which would establish a charter for this biological research station, suggesting a charter somewhat similar to that provided years ago for the Smithsonian Institution. The proposal has the general approval of the Secretaries of Agriculture, War, Treasury and the Smithsonian Institution, as well as that of the National Academy of Sciences. The proposal provides for the establishment of a Board of Directors composed of the Secretary of War, the Secretary of Agriculture, the Secretary of the Smithsonian Institution, President of the National Academy of Sciences, and 3 distinguished biologists of the United States of America. In directing the affairs of the Canal Zone Biological Area, the Board of Directors would have the assistance of an executive officer and a resident manager and would be authorized to receive and disburse funds which would be deposited in the Treasury of the United States. It is understood that a bill embodying these and other features may be presented to Congress for consideration during the coming session and that such a bill may be introduced into the Senate by Hon. Harry F. Byrd of Virginia. The Chairman of the Division of Biology and Agriculture has suggested that societies affiliated with the Association may wish to advise Senator Byrd of their interest in such a proposal.

The special committee of the Division of Biology and Agriculture appointed to confer with the Board of Governors of the Crop Protection Institute with reference to broadening and modifying the scope of the work and inquiring into its general objectives submitted a report which was approved by the Division. The report of this Committee includes a statement which is thought may be of interest to scientific organizations associated with the activities of the Crop Protection Institute. This statement follows:

**Suggested Statement to be sent by the Division of Biology and Agriculture of the National Research Council to the Societies Affiliated with the Crop Protection Institute.**

*MEMORANDUM WITH REFERENCE TO THE CROP PROTECTION INSTITUTE*

At its annual meeting in April 1938, the Division of Biology and Agriculture of the National Research Council provided for the appointment of a Special Committee to confer with the Board of Governors of the Crop Protection Institute regarding the possible broadening and modifying of the scope of work and to inquire as to the general objectives of the Crop Protection Institute. The Special Committee submitted its report at the annual meeting of the Division of Biology and Agriculture held April 1939, a brief summary of which is here presented for the information of other organizations interested in the Crop Protection Institute. The Committee advises that in carrying out its assignment they had the hearty cooperation of the Board of Governors of the Crop Protection Institute and that during the conference a number of matters of mutual interest were discussed in some detail.

The Board of Governors of the Crop Protection Institute advised the Committee that they did not believe it feasible or practicable to broaden the scope of activities of the Crop Protection Institute which are now defined by the Board of Governors as:

> "to make possible a relationship between industry and experts in the plant and animal sciences through which appropriate problems of industry and of science may be solved, more effective and safer control of harmful organisms may be developed, the boundaries of scientific knowledge may be enlarged, and the public welfare may be served."

The Board of Governors of the Crop Protection Institute supplied the Special Committee with considerable detailed information as to the procedure and policy followed by the Institute in selecting the individual investigators assigned to the various projects. From the information supplied the Special Committee concluded that it could suggest no better plan for the selection and supervision of individuals than that followed by the Board of Governors and expressed the belief that the Crop Protection Institute should be commended for the policies and procedures followed in this respect.

The Crop Protection Institute was conceived as an independent organization responsible for the aims and ideals for which it was established. To carry out the ideals and to assure that its Board of Governors consists of qualified representatives in the several fields with which it is concerned various organizations have annually designated individuals to serve as members of the Board of Governors. This procedure gives assurance that the Board of Governors will have the advantage of information available to specialists in the particular fields covered by such organizations. It does not, however, presume that the organizations which nominate the individuals are responsible for actions of the Board of Governors. The Special Committee indicated that it believed the relationships between the various organizations and the Crop Protection Institute have always been clearly defined. It further suggested that the practice followed by some organizations of designating individuals as their representatives on the Board of Governors of the Crop Protection Institute might imply a different relationship. The Committee suggested therefore that it may be well for various organizations to consider the desirability of indicating that the individuals whose names are presented to the Board of Governors are nominees which they may select. It further suggested that more than one nominee might be presented for each position and advised they were informed that such procedure would be agreeable to the Board of Governors of the Crop Protection Institute. The Division of Biology and Agriculture of the National Research Council proposes to use the designation "nominee" rather than "representative" in presenting names to the Board of Governors of the Crop Protection Institute.

The report of the Special Committee also suggests that since the Crop Protection Institute is an independent unit, responsible for its operations, various organizations which receive reports on the operation and activities of the Institute accept such reports as information.

S. A. ROHWER

## REPORT OF THE COUNCILORS TO THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

There have been but two meetings of the Council. The details of the business transacted are of no particular interest to this Association. At the first session, statistics covering membership were presented; plans for increasing registration were discussed; the desirability of revising the constitution and by-laws was indicated and given some consideration; a report was made with respect to the publication of several symposia; and resolutions were passed referring certain of these matters to committees for review prior to any action thereupon by the Executive Committee of the Council. At the second session, the affiliation of four societies (The American Society of Tropical Medicine, the National Malarial Society, the American Society of Agricultural Engineers, and the American Society of Plant Taxonomists) with the Association was approved; the appointment of a committee to arrange for semi-popular scientific lectures was authorized; the report of the committee on grants was accepted without reading; several members were elected as emeritus life and annual members and as fellows; support was given action directed toward the control of stream pollution; Philadelphia, Dallas and New York City were selected as the locations for the winter meetings of 1940, 1941 and 1942, respectively, with Cleveland as a preference for 1943 being referred to the Executive Committee for further consideration; Dr. A. F. Blakeslee, of the Carnegie Institution of Washington, representing Botany, was elected president for the ensuing year.

JAMES I. HAMBLETON
L. A. STEARNS

## REPORT OF THE REPRESENTATIVE ON THE COUNCIL OF THE UNION OF AMERICAN BIOLOGICAL SOCIETIES

Pursuant to action taken by the Executive Committee at Richmond, a committee consisting of C. E. Palm and myself was appointed to consider with a similar committee consisting of A. C. Kinsey, H. B. Hungerford, Alvah Peterson, W. A. Riley, C. H. Richardson, C. L. Fluke, and J. S. Houser, representing the Entomological Society of America, the possibility or desirability of enlisting more fully the support of the entomological societies for *Biological Abstracts*, and of considering ways whereby *Biological Abstracts* may be made more useful to entomologists generally. Your representative has discussed these questions with Doctor Palm and with the Chairman of the Committee of the Entomological Society of America. There has been no opportunity for the two committees to meet as a whole.

Dr. George W. Hunter, III, Secretary of the Union of American Biological Societies, wrote under date of September 13, at the suggestion of the Executive Committee of the Board of Trustees of *Biological Abstracts*, for advice with reference to the publication in 1940 of Section E of *Biological Abstracts* which covers entomology. He indicated that at the present time there are only 85 subscribers to this section and that it was the feeling of the editor that something should be done to make the section more useful. A series of specific questions were presented, which were discussed by me and Doctor Palm and, informally, with a number of other members of the American Association. As it was desired by Doctor Hunter to obtain some reaction to possible modification of Section E as a guide to determining policy for the coming year, which could not wait for formal action at the Christmas meetings, the reaction of the committee was sent to Doctor Hunter with the statement that the viewpoint expressed represented only that of the committee and a number of individual entomologists with whom the general problem had been discussed. The questions asked by Doctor Hunter and the replies are given below:

(1) Should Section E be expanded in its present form?

Reply was made that it is doubtful that an expansion of Section E can be made with present facilities which will enable it to obtain any considerable additional support from entomologists who already have access to present abstracting journals, and that it would appear to be an unjustified financial hazard considering the experience of the past year and any probable indications we now have of an expanding demand.

(2) Should Section E be expanded or amplified in any way so as to enhance its value to the entomological group?

It was the reaction of the committee that there is no question that Section E could be expanded and amplified in such a way as to enhance materially its value to entomological workers. This is particularly true in the taxonomic sections, which have been critized rather severely by taxonomic workers generally because of their inadequacy. The general inclination of economic entomologists seems to be to look upon the services of *Biological Abstracts* rather skeptically in comparison with the *Review of Applied Entomology* and few are willing to subscribe to both journals or to discontinue subscription to the one which has been satisfactory in the hope that the new one will fill the need.

(3) Would there be any likelihood of securing support from one or more of the entomological societies for Section E? Is there any likelihood that we could get them to come to *Biological Abstracts* with a definite plan of support?

The reply of the committee indicated that, from the general opinion obtained through discussing *Biological Abstracts* with entomologists of the Association, it is not believed that there is much likelihood they will be willing to subsidize *Biological Abstracts* directly. Attention was called to the fact that the situation is quite different from that of the bacteriologists, who have been cited as coming to the financial support of *Biological Abstracts*, because their dependence for abstracting services lies in maintaining that offered by the *Abstracts*.

(4) Would the entomologists be interested in subscribing to Section E if *Biological Abstracts* could announce that all societies securing subscriptions from a given percentage of their membership (say 30%) would be allowed a reduction of one dollar in the subscription price?

The reply was made that it is not believed that the deterring factor in subscription to *Biological Abstracts* is the difference between the present cost of six dollars and the suggested reduction of five dollars. Although it is believed that the six dollar subscription is considered rather high for what is being received, the essential consideration is that most economic entomologists who can subscribe to an abstracting journal are already subscribing to the *Review of Applied Entomology*.

It was further stated in the reply of the Chairman of the committee that it was the feeling that these statements rather accurately present the situation, that there is no use in attempting to created a false hope in regard to support of the *Abstracts* or in creating an artificial demand, and that possibly the wisest procedure would be to eliminate the section designed to cover entomology specifically and to spend the funds thus saved on sections in which there is a real demand for abstracting service. This would enable the *Abstracts* to husband its resources during the present critical period, with the future possibility of including the entomological field when, and if, a demand arises which will stimulate adequate support from entomological workers.

It was further stated that we could not claim to speak for the Association nor for entomologists generally, but were merely giving what was believed to be the rather general attitude, and that the questions raised would be presented to the Executive Committee for such action as they might wish to take.

Attention is directed to the recent announcement by the trustees that a reduction of one dollar in the current price for each section is offered to the members of societies thirty per cent of whose membership subscribes for 1940.

Your representative attended the annual meeting of the Council of the Union of American Biological Societies held at Richmond last year. At this meeting reports on the progress of *Biological Abstracts* and means for placing it on a sound basis were discussed. A report was also presented from the Committee on Biological Science Teaching which has sponsored the establishment of the National Association of Biology Teachers which is now organized and operating.

The annual meeting of the Council for this year

is scheduled for Thursday afternoon, December 28. At this meeting a report will be presented on *Biological Abstracts* and plans for publication of the 1940 volume will be discussed. There will be consideration given to a proposal to amend the constitution of the Union of American Biological Societies, to permit the establishment of a second class of membership to be known as "individual memberships"—to provide that any member of any of the constituent societies could become an individual member of the Union by paying dues. According to the proposal, all persons joining the Union as individuals under such a plan would join because they desired the chance through such an organization to support financially and work individually and with others for certain large objectives and purposes mainly outside the scope of special interest of any of the constituent societies but all important to the general field of biology. It has been suggested that such activities might include more effective aid in support of *Biological Abstracts*, to which part of the dues might be allocated; promotion of public biological interest; promotion of research on important scientific or national problems having biological basis; support of important movements in the interests of biologically sound legislation, such as relate to human nutrition or human health; the encouragement of efforts looking to more adequate biological education at the college and at the adult level; management of permanent legacies or endowments for fellowships and scholarships in the biological sciences; etc. It is further suggested by the proposers of this expansion in the Union that there would be no reason why the officers and Executive Committee of the Union should not continue just as formerly, but they would be able through the new membership body to carry out functions now difficult or impossible for the Union because it can act only through a council which is responsible to the constituent societies. This proposal is presented at this time to the Executive Committee so that its representative may be instructed as to the attitude of the Association should this be desired.

Respectfully submitted,
P. N. ANNAND

## REPORT OF THE COMMITTEE ON INSECTICIDE TERMINOLOGY

Your Committee on Insecticide Terminology has considered numerous questions that have been brought to its attention during the past year. We offer the following further procedure for the guidance of authors of entomological papers and the Editor of the JOURNAL OF ECONOMIC ENTOMOLOGY.

1. In order to secure uniformity and clarity among authors in expressing the amounts of insecticides and fungicides used in spray and dust formulations employed in field experiments, we recommend that:

a. The reference unit for diluted field control spray formulations shall be stated in terms of avoirdupois pounds or ounces or fractions thereof.

b. The weights of the solid components used in field sprays shall be stated in terms of avoirdupois pounds or ounces or fractions thereof.

c. The quantity of liquid insecticides and fungicides employed in field sprays shall be expressed in terms of United States fluid measure, i.e., in gallons, quarts, pints, or fluid ounces or fractions thereof.

d. Contributors to the JOURNAL OF ECONOMIC ENTOMOLOGY outside of the United States should clearly indicate in their manuscripts the units of measurement used by them. If they have not used the system recommended in paragraphs a, b, and c above, their systems will be translated by the Editor into the units recommended, but the original expression will be published in parentheses or in footnotes for the convenience of those who are accustomed to other systems of measurements.

e. The use of mixed expressions, such as solids in pounds per 100 gallons and liquids expressed in percentage by volume or volume ratio (referring to volume dilution) should not be used. As an example of the wrong and right methods of expressing the composition of a spray mixture the following is cited:

| *Wrong* | *Right* |
|---|---|
| Lead arsenate 3 lbs. | 3 lbs. |
| Summer oil emulsion 3 qts. | 3 qts. |
| "*Black Leaf 40*" 1:800 or 0.125% | 1 pt. |

f. Under no circumstances should solids in field spray formulations be expressed in percentage concentration due to the confusion that has arisen as to whether the undesirable, ambiguous weight /volume or the correct weight/weight relationship is referred to.

g. In dust mixtures, the active ingredient or ingredients should be stated first, followed by the other constituents used in a given composition. Colons to express the ratio of all ingredients present should be used instead of dashes as is now frequently done and which often leads to confusion. The following are examples of the correct way for expressing dust composition: cubé (5 per cent rotenone), flour, talc 1:1:3 by weight; or monohydrated copper sulfate, calcium arsenate, flour, lime 20:10:10:60 by weight.

With regard to dusts containing nicotine, not only the nicotine content of the finished product, expressed as percentage by weight, but also the formula showing the nature and weight of all constituents as used in the preparation should be given. Examples are the following: 3 per cent nicotine dust prepared from "*Black Leaf 40*," calcined gypsum, lime, 7.5:7.5:85.0 by weight; or 3 per cent nicotine dust prepared from "*Black Leaf 50*," tobacco dust (0.5 per cent nicotine) 5:95 by weight.

2. *Definitions applying to common compounds.*

a. *Lead arsenate.* We recommend that the term "lead arsenate" as now commonly used without specification as to kind should be restricted to and designated as always applying to *acid* lead arsenate. In view of the reawakening interest in basic lead arsenate for use on plants noticeably susceptible to arsenical injury, when an author uses any kind of lead arsenate other than *acid* lead arsenate this should be very clearly stated.

b. *Calcium arsenate.* In view of the fact that the term "commercial calcium arsenate" applies to products which naturally contain two or more definite kinds of compounds of calcium and arsenic, we recommend that wherever possible the authors of papers dealing with calcium arsenate specify the molecular ratio or the amounts of calcium and arsenic which are actually combined. If this cannot be done, trade labels or other clarifying reference to the products used should be made. The use of letters and numbers alone to designate commercial products is meaningless.

3. *Definition and general classification of chemicals used in pest control.*

a. To clarify any present confusion and to avoid

future perplexity with regard to the broad, general classification of chemicals used in insect control based on their mode of action, your Committee recommends the adoption of the system used by Metcalf and Flint, "Destructive and Useful Insects" Second Edition (1939) p. 238–239.

b. We further recommend that the term "attrahent," used in designating chemicals for attracting insects to baits or traps, be dropped. We propose that the term "attractant," which is recognized by the Second Edition of Webster's International Dictionary (Unabridged), be used instead.

Your Committee has not been able to agree unanimously on a suitable definition for toxicity, and on a suitable term to be used for expressing the field performance of chemical control products where factors other than lethal action may be involved.

Your Committee wishes to call attention to Item 4 of its report last year as published in the JOURNAL OF ECONOMIC ENTOMOLOGY **32**(1):169:1939 which applies to the frequent misuse of the term "rotenone" when ground derris, timbo, or cubé or extractives of these roots is meant. Although such misuse has been largely avoided in print, it occurs all too frequently in speech.

Respectfully submitted,
WILLIAM MOORE
C. M. SMITH
F. L. CAMPBELL
R. H. ROBINSON
HARRY F. DIETZ, *Chairman*

## REPORT OF THE COMMITTEE ON COMMON NAMES OF INSECTS

During the past year your Committee has received proposals for common names of 41 insects. It has received suggestions for changing 20 names already approved, and has received suggestions for 3 names as additional names for insects, of which the Association has already approved one name. It is suggested that as heretofore this list be sent to all members of the Association in order that they may have opportunity to vote on these names, and that if 20 per cent or more of the votes cast for any given name are in opposition to that name it will be rejected, and that all the other names will be considered as accepted. The Committee further recommends that the names so approved be published in the JOURNAL as a supplement to the list published in Volume 30, pages 527 to 560, 1937.

During the past year, we found a decided improvement in the consideration that members were giving to the proposed names sent to them for approval, and for the most part the members only voted on those names in which they had an interest. There seems to be considerable misunderstanding as the names proposed as additional names, and many voted against these additional names with the understanding that they would supersede the name already approved. This is not the intention. It is intended that the additional name will give the insect two or more approved names. We believe this to be highly advisable for such insects as *Heliothis armigera*, which has widely used local and crop names.

J. A. HYSLOP, *Chairman*
ROGER B. FRIEND
T. E. SNYDER
CLAUDE WAKELAND
K. M. KING
D. M. DELONG

## REPORT OF COMMITTEE ON CODLING MOTH

The Committee has continued its activities very much as in previous years. Since 1933, arrangements have been made each year with the Bureau of Entomology and Plant Quarantine to bring together mimeograph, and distribute summary reports on codling moth work carried on by various investigators throughout the United States and Canada. In this way current information has been made available to interested entomologists considerably sooner than the material could reach them through the usual channels of publication, and the early circulation of this material has assisted workers in planning the following season's program to best advantage. This service seems to have met with very general approval and is being continued for the codling moth season of 1939. Invitations to contribute to the pool of information were sent out during December, and the material will be mimeographed in January.

As indicated in the report of last year, no conference was attempted during the winter of 1938–39. There seems to be no very active demand for a conference during the present winter, and for the present the Committee is, therefore, not making plans to sponsor another conference.

B. A. PORTER, *Chairman*
R. L. WEBSTER
H. N. WORTHLEY
C. R. CUTRIGHT
W. S. HOUGH
W. A. ROSS

## REPORT OF THE COMMITTEE FOR THE PROMOTION OF OFFICIAL ENTOMOLOGY

In the past years the activities of this Committee have been devoted primarily to assisting in securing adequate funds for the operation of the Federal Bureau of Entomology and Plant Quarantine. During the past year there has been no need for such assistance.

The question has been raised regarding the problem of public patents for devices used as insect controls, and especially to a point where it can be definitely recommended to the public. Unless a public patent is concerned with a matter of such importance to the life of the commonwealth as to render its employment a matter of strong necessity, it may operate as a bar to the development of the very thing which it was intended to promote, because it has no monopolistic features. In other words, no industrial concern is likely to feel that it can afford to spend money on its practical development, because whatever it learns about the manufacture and handling of the public patent-covered proposition is available to any other manufacturer.

We are referring to this problem because it has been called to our attention by several of our members who thought it was a situation to be considered by this committee. We have conferred with officials of the Federal Bureau of Entomology and Plant Quarantine and learn that they are vitally interested, are making a thorough study of the problem, and expect to be able to offer a possible solution, or at least suggestions, a year hence.

T. J. HEADLEE
G. A. DEAN
J. J. DAVIS, *Chairman*

## REPORT OF THE CROP PROTECTION INSTITUTE

In the current year productive work has continued at about the same level as in previous years. There has been increased emphasis on projects supported by industrial organizations of large size in which the company's research organization actively cooperates with the Institute's research men. In the experience of the Institute this type of work is most productive of fundamental results.

When research men in the laboratories of a supporting company can give their time and attention to the development of new compounds, when these can be studied from their biological point of view by the Institute workers, and when, in turn, the results of this study can become the basis of further work in the laboratories of the supporting company, a constructive program is under way out of which can be expected to emerge new and better materials for the control of serious plant diseases and insects. Out of this, also, will come a steadily expanding knowledge of the relationship of chemical structure to toxic properties against fungi or insects, and thus a significant broadening of scientific horizons.

The continued state of uncertainty and stringency in the industrial world continues to have its effect on support for research. When an industry is accumulating a surplus it feels that it can readily devote a part of such earnings to long-term investigations, looking toward the future. When it is not able to earn a surplus it may still maintain a research program, but it does so with many reservations.

In 1939 the Institute has directed projects for the following companies:

NATIONAL ANILINE AND CHEMICAL CO., INC.
RÖHM AND HAAS COMPANY.
SHELL OIL COMPANY, INC.
STANDARD CHEMICAL PRODUCTS, INC.
CARBIDE AND CARBON CHEMICALS CORPORATION.
DOW CHEMICAL COMPANY.
GENERAL CHEMICAL CO., INC.
UNITED STATES RUBBER COMPANY.
SHERWIN-WILLIAMS COMPANY.

The following projects were directed by the Institute in 1939:

*An exploration of new organic contact insecticides and fumigants.*—This work was begun in August as a tentative program, projected for a period of six months, but with prospect of continuance into a long-term undertaking. The company, in its own research laboratory, had already explored some of its organic materials as fumigants. It had assigned to this undertaking an able chemist of its own staff. The Institute set up a project under which it has taken over the biological aspects. The work was placed at the Indiana experiment station, under the supervision of Prof. J. J. Davis. A committee was set up which supervises this project and the one described in the following paragraph, and which consists of J. J. Davis, S. E. A. McCallan, H. W. Thurston, Jr., and W. C. O'Kane. Dr. E. N. Woodbury, a graduate of Ohio State University, was employed as investigator.

*An exploration of new organic fungicides.*—As with the preceding project, this investigation was begun in August, was projected for six months, is quite likely to continue in a substantial long-term project, and is under the supervision of the same committee noted above. Dr. R. H. Wellman, a graduate of the State College of Washington, was employed as investigator. The initial work was placed at the Boyce Thompson Institute, under the supervision of Dr. S. E. A. McCallan.

*A survey of the present status of the soil-less culture of plants.*—This undertaking began the first of August and is just now completed. It was organized in cooperation with the Boyce Thompson Institute, with Dr. William Crocker as chairman of our committee. Participating also, especially in examination of results and conclusions, are Dr. J. M. Arthur, of Boyce Thompson Institute staff and Dr. Howard P. Barss. The Institute secured the services of Dr. Forman T. McLean to conduct the actual survey. Dr. McLean has visited the experiment stations where work has been done in soil-less culture, or so-called "hydroponics." His visits were planned to make him thoroughly familiar with what had been done at the various stations and with the findings and beliefs of the station men engaged in this work. He has visited all installations of size in the United States, including the West Coast, and has looked over the work in Canada. All told, the work includes seventy-one installations. In brief, the trend of results indicates that soil-less culture in one form or another is meeting with a certain amount of success in the hands of able and experienced commercial men, but is not adapted to utilization by the amateur or the inexperienced.

*Insecticidal properties of various nitro compounds*—This was a continuation of our work of previous years. Its object is to develop new contact insecticides, either in liquid or in dust form. It has resulted in the practical utilization of di-nitro ortho cyclo hexyl phenol, both as a toxicant in a dormant spray and as an impregnating material of walnut shell flour for use on the West Coast. The work was done at the Riverside station, in California, under the immediate supervision of Dr. A. M. Boyce. Dr. J. Franklin Kagy was employed as investigator with George McCall as assistant. The company has now established a West Coast branch and has set up its own organization.

*Control of truck crop diseases in Louisiana.*—This work was begun last year and has continued. It is under the supervision of Dr. C. W. Edgerton and Dr. A. G. Plakidas. It involves applications of sulphur materials, and of copper materials, in control of diseases affecting strawberries and cucumbers.

*Applications of fungicides to peanuts.*—These tests have occupied the present growing season and involve copper materials and sulphur materials. The work was under the supervision of Dr. Robert F. Poole.

*Addition of adhesives to lead arsenate and calcium arsenate.*—This work is a continuation of that of last year, and involves field plot studies of the efficiency of arsenicals with and without adhesive, in control of cotton leaf worm, cotton boll weevil, and some truck insects. The work has been conducted in Mississippi under the supervison of Prof. Clay Lyle.

*Further tests of detergents as fugicides and contact insecticides.*—This is a short-time continuation of work carried out in previous years. The spore tests were carried out at the New Haven station, and the tests on *Aphis rumicis* at the New Hampshire station.

*Studies of cuprous oxide.*—The object of this work is to develop new and better compounds in which cuprous oxide is the active substance, and to improve the cuprous oxide itself, both from the viewpoint of fungicidal activity and from that of safety on plants. Substantial information of scientific value

is accumulating. The project is under the supervision of a committee consisting of J. G. Horsfall, W. H. Martin, and S. E. A. McCallan. The work has been conducted at the Geneva, N. Y., station, but since Dr. Horsfall has transferred to the Connecticut station, at New Haven, the headquarters of the work were moved to that point, this last summer. Dr. J. W. Heuberger continues as a member of the Institute staff engaged in this investigation, in which the technical men of the supporting company's laboratories work to meet and solve the problems developed by the biological work of the Institute men.

*Investigation of a nitro compound as an herbicide.*—The material carries the trade name "*Sinor.*" In extensive work in the East it showed excellent properties as a selective weed killer. Because of the importance of weeds in Pacific Coast crops, the headquarters of this project were transferred to California, and the Institute's investigations were placed under the supervision of Prof. W. W. Robbins, of the California experiment station staff. W. A. Westgate continued in the employ of the Institute as research man, with Jack D. Matley and W. F. Singleton as assistants. Very extensive field plots were laid out in various parts of California. Improved apparatus was developed. Some applications were made by airplane. Thorough studies were made of the effects of soil moisture and air moisture on weed-killing properties. Excellent control of some weeds of first rank was secured.

*A preliminary study of the repellent properties of a material for incorporation in oil sprays.*—This short-time project was intended as an exploratory piece of work, designed to indicate whether the repellent had sufficient merit to be worth a long-term project. The material did not show adequate promise. Therefore, at the suggestion of the Institute, the work was discontinued.

*Research in organic fungicides.*—The object of this and the following projects is to explore a long series of organic chemicals developed in the research laboratories of the supporting company. This work, and the several projects that follow, is a continuation and expansion of the exploratory work reported a year ago.

The supporting company is maintaining active chemical research in the development of these various materials. The work has its headquarters at the Connecticut experiment station, under the superivision of J. G. Horsfall. The supervising committee of this, and the following projects, includes J. G. Horsfall, E. N. Cory, and W. C. O'Kane. Dr. Eric Sharvelle was employed in the fungicide investigations until September 30, 1939, when he accepted a more permanent position elsewhere. His place has not yet been filled. Mr. George E. O'Brien was employed, beginning last spring, in supplementary work on the use of some of these organic compounds on fruit diseases, under the supervision of Dr. J. M. Hamilton. He is continuing on this work under Dr. Horsfall's direction.

*Research in organic stomach poisons and repellents*—Various aspects of this work have been conducted at various places, including the Mississippi station, under Clay Lyle, Ohio State University, under D. M DeLong, New Hampshire station, under W. C. O'Kane, and the Maryland station, under E. N. Cory. A number of the materials show promise as definite repellents which tend to be more or less specific in their character, being effective against certain insects but not effective against others. A few materials show some promise as stomach poisons but the most promising results are in the field of repellents. The men who have been employed in this work from time to time include Stuart Edmond, J. H. Guill, Jr., Richard N. Hofmaster.

*Organic compounds as contact insecticides and oricides.*—These studies have been located at the Maryland and the New Hampshire stations. Almon M. Lord is employed, with Robert J. Norton as occasional assistant. Many compounds have been under study, among these a synthetic oil which is a solvent for derris resin. Because of the unusual solvent properties of this oil, it is possible to incorporate in a contact spray a larger percentage of derris toxicants than hitherto could be included.

*Investigation of fumigants.*—This work is conducted at the Entomology research laboratory at the University of New Hampshire, where equipment for this type of investigation is available. Stuart Edmond is employed.

*Investigation of various organic substances as mothproofing agents.*—Rather marked progress has been made in this project. Three or four materials show definite promise. Almon M. Lord is carrying on this work, which is located in the research laboratory at the New Hampshire station.

*Stabilization of derris.*—The object of this project is to develop a stabilizing agent for powdered derris and derris extracts through use of antioxidants. Three materials have been discovered which appear to prolong the life of derris powder when exposed to sunlight.

*Control of potato diseases and insects with basic copper arsenate.*—The object of this project was to secure information on the relative value of basic copper arsenate as compared to Bordeaux mixture in control of early blight and late blight of potatoes, and the relative performance as compared to calcium arsenate in control of leaf-eating potato insects. The work was done in Maine, in cooperation with the Maine experiment station and under the supervision of Dr. Reiner Bonde.

In addition to the above projects, several items of initial exploratory work have been conducted in the course of the year, as in other years. None of these has yielded anything outstanding.

The Institute feels that it has had a year of significant development and that major investigations under way will lead in time to major discoveries and improvements in the field of activity for which, primarily, the Institute was organized.

W. C. O'KANE, *Chairman*

## REPORT OF COMMITTEE COOPERATING WITH PEST CONTROL OPERATORS

Your Committee begs leave to report as follows:

1. *Cooperation between pest control operators and entomologists.*—We have observed a continued broadening of cooperation between pest control operators and entomologists during the past three years, much of which is due to acts of the National Pest Control Association. At Memphis in 1937, Omaha in 1938, and New York in 1939, that association extended hospitality to the entomologists, inviting them to attend these annual conventions. The invitations have been accepted by a number of entomologists and since the entomologists who attended each convention were, for the most part, persons from states near the site of the convention, a different group of entomologists was present at each, so that perhaps 40 or more different well-

known official entomologists have had contact with the pest control industry through the medium of the N. P. C. A. conventions during the past three years. To our knowledge all have been impressed with the type of men connected with that association and with their sincere effort to develop this important entomological industry into an ethical business which will rank as a profession.

This cooperation and better understanding has been greatly helped by our Association, inasmuch as one or more of the regional meetings have devoted a half day of their sessions to problems of the commercial pest control operator, to which the pest control operators of the region have been invited.

The regional Pest Control Operators' Conferences have also been of immeasurable value in promoting cooperation between the two groups and better standards of ethics, as well as being of educational value. Three such annual conferences have been held at Purdue University for the operators of the Central West and East, two have been held at Stanford University and the University of California for the West Coast and one at Louisiana State University for the South. These will be continued in 1940 and thereafter as annual events. It is hoped that one will be inaugurated in the East in 1941, so that eventually there will be four regional educational conferences annually to take care of the needs of the United States and Canada. It should be noted that all of the institutions where the conferences are held receive cooperation from nearby states, as well as from the federal Bureau of Entomology and Plant Quarantine.

There is no question that the cooperation on the part of the entomologists is appreciated by the pest control operators, and that there is being developed in the important entomological field of pest control service a nucleus of ethical operators who will eventually eliminate from the industry most of the unethical operators and those who have been responsible for degrading the industry. This cooperation is also borne out by the fact that ten commercial operators, from as far east as New York and as far west as Chicago, are attending the meetings here at Columbus.

2. *Legislation.*—We wish again to go on record as definitely favoring proper state legislation of the pest control industry rather than city legislation. It has not yet been possible to develop a model law, but it is hoped that such a model law may be formulated in the near future and circulated among the membership of this Association and the National Pest Control Association for critical consideration.

3. *Pest Problems.*—Entomologists may well be criticized for failure to give adequate attention to problems confronting the pest control operator, and on the other hand pest control operators may be ciriticized for failure to demand assistance. We urge entomologists to become acquainted with the commercial pest control operators of their states and to attempt to familiarize themselves with the problems which call for research. Pest control operators can be of material assistance by securing adequate appropriations for state as well as federal research agencies.

4. *Fraudulent Operators.*—There are many persons calling themselves pest control operators who are unqualified because of ignorance or who knowingly use fraudulent practices. They are obtaining hundreds of thousands of dollars from our citizens and at the same time injurying the reputable operators. This situation applies primarily to termite operators. Recently a ringleader operating in Indiana and Illinois was sentenced to one to seven years in the Indiana State Reformatory, for malpractice, that is, obtaining money under false pretenses. Four others are in jail awaiting trial. Entomologists are urged to cooperate with prosecuting authorities and to give adequate publicity to the end that these fraudulent operators be eliminated so far as possible.

E. A. BACK
W. P. FLINT
J. J. DAVIS, *Chairman*

## REPORT OF THE COMMITTEE ON ENTOMOLOGY IN RELATION TO CONSERVATION

The correlation of entomological work with various other conservation activities continues to be of great importance to national welfare. Entomology intimately and vitally touches each and every one of the major conservation fields such as flood control, soil conservation, forest improvement, and wildlife restoration.

It is only by an exchange of ideas between entomologist and those concerned in the execution of the vast conservation program now under way, the consideration of entomological problems in planning that program, and the utilization of information already at hand or which may be derived from experience as the program is put into effect that the best interests of the country will be served.

The present large scale and widespread efforts in the direction of conserving our forests, preventing floods, checking soil erosion, and fostering wildlife resources not only demand that the best available entomological knowledge be built into the programs, but gives an exceptional opportunity for gaining reliable information on the effect of certain procedures on insect abundance and insect damage.

Your committee therefore urges the entomologists of the country to participate actively in the planning of conservation measures and to take full advantage of the opportunities offered by conservation work to gather and record much needed information on the relation of different types of land use and conservation procedures to insect problems.

The committee invites members of the Association to present to it their suggestions as to how it may aid in coordinating entomological and other conservation work.

S. A. GRAHAM
F. C. BISHOPP, *Chairman*

## REPORT OF THE MEMBERSHIP COMMITTEE

Your Committee on Membership takes pleasure in submitting with its approval the nominations of one hundred and fifty-seven persons, correctly endorsed, and with required dues advanced, for active membership in the Association at this session.

In addition, there have been fifteen reinstatements.

Since the last meeting we have lost thirteen members by resignations and ten by death.

Two active members have become Life Members during the year.

Respectfully submitted,
C. L. METCALF
A. F. SATTERTHWAIT, *Chairman*

NAMES OF PERSONS ELECTED TO MEMBERSHIP, FIFTIETH ANNIVERSARY MEETING*

Adams, Eugene, Norman Park, Ga.
Algert, E. D., Box 1656, Nogales, Ariz.
Anderson, Bertram R., 3511 Bisbee St., El Paso, Texas
App, Bernard A., 4700 Music St., New Orleans, La.
Arnold, C. H., 414 E. 12th Ave., Columbus, Ohio

Baker, Thomas J., 439 U. S. Court House, Portland, Ore.
Barnett, Theodore A., 208 Potrero Ave., Nogales, Ariz.
Baskin, Wm. H., P.O. Box 227, Port Arthur, Texas
Beard, Raimon L., Agrl. Expt. Sta., New Haven, Conn.
Bellis, Charles E., 216 Potrero Ave., Nogales, Ariz.
Bemis, Willard G., 641 Washington St., New York, N. Y.
Beougher, Judson J., Laurelville, Ohio
Bertholf, Lloyd M., Western Maryland College, Westminster, Md.
Brooks, James Welton, King Hall, Univ. of Wis., Madison
Brown, Harry E., Box 244, Elsberry, Mo.

Cannon, Thomas M., 11 Crestview Ave., Springdale, Conn.
Carlson, F. W., Box 243, Yakima, Wash.
Carpenter, Thomas Lyman, King Hall, Univ. of Wis., Madison
Cely, Homer Mills, 237 W. Strickland St., Del Rio, Texas
Chamberlain, J. J., 102 W. Norman Ave., Dayton, Ohio
Chapman, Thomas P., Box 277, Laredo, Texas
Chapman, William W., 308 Custom House, New Orleans, La.
Christian, Moss B., Tallulah, La.
Chubb, Henry S., Box 2302 Univ. Station, Gainesville, Fla.
Conkle, Herbert J., P.O. Box 413, Arlington, Va.

Daley, Caleb P., 308 Custom House, New Orleans, La.
Daniels, Charles H., Insecticide Laboratory, Beltsville, Md.
Dean, Horace S., 2621 University Place, Washington, D. C.
Denning, J. Allison, 4452-a Russell St., St. Louis, Mo.
Deputy, O. D., Box 909, Brownsville, Texas
Dickinson, Berton C., O. S. U., Columbus, Ohio
Dickson, R. C., Dept. of Ent., Citrus Expt. Sta., Riverside, Calif.
Dieter, Curtis Earl, King Hall, Univ. of Wis., Madison
Dillard, W. T., 308 Custom House, New Orleans, La.
Dorland, LeRoy, 541 Texas Ave., Mercedes, Texas
Dugas, Alvan L., Agrl. Center, Expt., Sta., University, La.
Durham, Victor C., Room 601 Custom House, Philadelphia, Pa.

Edwards, E. E., 614 N. Illinois St., Indianapolis, Ind.
Eldredge, Bartlett W., c/o Waltham Chemical Co., 118 Calvary St., Waltham, Mass.

Fellton., Herman L., Box 207, Liberty Corner, N. J.
Fox, Clarence C., Rt. 2, Wenatchee, Wash.
Franklin, J. R., 615 State St., Hammond, Ind.

Galloway, A. Gordon, B. E. P. Q., Washington, D. C.
Gammon, Cyril, 1784 La Paz Rd., Altadena, Calif.
Gammon, Earle T., 2406 E. Mountain St., Pasadena, Calif.
Gay, Geraldus, 217 U. S. Post Office & Court House, Norfolk, Va.
Glass, Edward H., Agrl. Expt. Sta., Blacksburg, Va.
Gobeil, A. R., Ent. Service, Dept. of Lands & Forests, Quebec, Can.
Goff, Corbin C., 4245 West Pine Blvd., St. Louis, Mo.
Goolsby, Warren C., 308 Custom House, New Orleans, La.
Gouldman, Henry Y., R. D. 2, Herndon, Va.
Graham, Owen Hugh, Box 1855, College Station, Texas
Granek, Irving, 367 Vernon Ave., Brooklyn, N. Y.
Greer, A. H., Box 191, Calexico, Calif.

Haddon, Una G., 308 Custom House, New Orleans, La.
Haller, C. F., 811 N. Estrella St., El Paso, Texas
Harris, Clarence S., Tech. Products Dept., Shell Oil Inc., St. Louis, Mo.
Harrison, Edgar Claude, Jr., 404 Rosemont St., Calexico, Calif.
Haug, Gordon W., Kelowna, B. C., Canada
Haynie, John D., 1603 E. Colonial Drive, Orlando, Fla.
Hofmaster, Richard N., R.R. 2, Fostoria, Ohio
House, Berry C., Box 277, Laredo, Texas
Hovey, Charles L., Div. Ent. & Zool., Univ. of Minn., Univ. Farm, St. Paul, Minn.
Howell, Dariel E., A. & M. College, Stillwater, Okla.

Jeppson, Lee R., 1951 Chesnut St., Apt. 304, Berkeley, Calif.
Johnson, George V., Beltsville, Md.
Jones, Clyde R., Findlay, Ohio
Jones, George M., Rt. 2, Mercedes, Texas
Jordan, Herman B., 1411 E. 20th St., Indianapolis, Ind.

Kadner, Carl G., Loyola University of Los Angeles, Los Angeles, Calif.
Kerr, Miller J., 344 Homestead Ave., New Orleans, La.
Kerr, Theodore W., Jr., Dept. of Ent., Cornell Univ., Ithaca, N. Y.

Lattimore, Robert B., Box 688, Nogales, Ariz.
Leary, John B. R., 1616 Salinas Ave., Laredo, Texas
Lewis, Arthur H., Box 913, Laredo, Texas
Lewis, J. Guy, 100 Custom House, Detroit, Mich.
Linger, Russell B., Box 606, Pensacola, Fla.
Littooy, Ed. H., 2598 Taylor St., San Francisco, Calif.
Locke, Clarence M., 127 U. S. Court House, El Paso, Texas
Lord, Almon M., Desmith Hall, Durham, New Hampshire
Lyttle, Nelson Edwards, 33 W. 10th Ave., Columbus, Ohio

* Four applications were received after the report of the Membership Committee was read, and were voted upon by the members at the final business meeting.

MacArthur, Kenneth, Milwaukee Public Museum, Milwaukee, Wis.
Malone, Milton S., 3909 Capital Ave., Houston, Texas
Manis, Hubert C., State College, Ames, Iowa
Martin, Dial F., College Station, Texas
Martin, George C., 1527 Lowerline St., New Orleans, La.
McClay, Arthur Thomas, 1062 47th St., Sacramento, Calif.
McGregor, W. S., College Station, Texas
McKenna, George F., Boyce Thompson Inst Yonkers, N. Y.
Metcalf, Robert L., 704 Pennsylvania Ave., Urbana, Ill.
Miller, Keim Eldon, 308 Custom House, New Orleans, La.
Miller, Virgil O., 229 New Federal Bldg., San Ysidio, Calif.
Mirimanian, Miriman S., Box 227, Port Arthur, Texas
Mitchell, James Harold, Box MM, Oxnard, Calif.
Moreland, James H., 308 Custom House, New Orleans, La.
Morris, O. D., Box 685, Houston, Texas
Morris, Samuel R., 1553 Eslava St., Mobile, Ala.
Muchnick, Sam, 129 12th Ave., Columbus, Ohio
Mulrennan, John A., Escambia Co. Health Dept., Pensacola, Fla.

Nicaise, Randolph W., Room 16 Custom House, Charleston, S. C.

Opitz, Charles F., 50-14 39th St., Long Island City, N. Y.
Osorio-Rojas, Jose Manuel, University of Habana, Habana, Cuba

Parker, Barbara M., 416 E. 47 Terrace, Kansas City, Mo.
Pechuman, L. L., Barry Lime Sulphur Co., Lyndonville, N. Y.
Peltier, Paul X., 327 Sonoita Ave., Nogales, Ariz.
Petrakis, Manuel M., State Natural History Survey, Urbana, Ill.
Pettit, A. K., Box 1881, El Paso, Texas
Petty, Howard B., Jr., 301 E. Chalmers St., Champaign, Ill.
Phillips, Arthur M., Box 1262, Sanford, Fla.
Pratt, Orlo A., Box 715, Calexico, Calif.
Prendergast, David T., 2345 D St., La Verne, Calif.
Price, Manning A., Box 1067, College Station, Tex.
Prince, Charles E., Jr., 16 University Rd., Calvert Hills, Hyattsville, Md.

Reagan, Eugene P., 5 Zaragoza St., Brownsville, Texas
Richardson, Maceo M., Box 416, Eagle Pass, Texas
Root, George A., 124 Potrero Ave., Nogales, Ariz.
Rowe, John A., State College, Ames, Iowa
Rowell, John O., State College, Raleigh, N. C.
Russell, George H., Box 438, Eagle Pass, Texas
Russell, Jack C., 541 Ferndale Rd., Gainesville, Fla.
Russell, John H., Box 821, Presidio, Texas

Schoening, Leroy, 229 Federal Building, San Ysidro, Calif.
Secrest, John P., 108 Spa St., Brentwood, Md.
Seiferle, Edwin J., Dept. of Chemistry, Ames, Iowa
Sennewald, E. Francis, 2723 Chouteau Ave., St. Louis, Mo.
Sheffield, Henry F., 105 Meade Ave., Passaic, N. J.
Sikes, James Herbert, Box 112, College Station, Texas
Slabaugh, Ruth E., Ent. Bldg., Univ. of Illinois, Urbana
Smith, L. G., Extension Service, Pullman, Wash.
Speers, Charles F., 120 E. Colvin St., Syracuse, N. Y.
Stalmach, A. A., Box 51, Rio Grande City, Texas
Stanger, Neal W., Jr., 4222 Shafter Ave., Oakland, Calif.
Steuk, William K., B. E. P. Q., Sandusky, Ohio
Stewart, Bernard P., 1217 Seymour Ave., Laredo, Texas
Still, George W., B. E. P. Q., Sandusky, Ohio
Stromberg, W. B. R., P.O. Box 802, Nogales, Ariz.
Stucker, Harry, 106 E. 19th St., New York, N. Y.
Sudduth, Warren R., Box 94, Naco, Ariz.
Sugarman, Bernard B., 709 W. California Ave., Urbana, Ill.
Swain, Ralph B., P.O. Box 714, Salt Lake City, Utah

Talbert, Edward L., P.O. Box 856, Laredo, Texas
Toffaleti, James P., 613 S. Ninth St., Gainesville, Fla.
Traub, Robert, Dept. of Ent., Univ. of Illinois, Urbana
Trigg, Robert L., 3709 Avenue T., Galveston, Texas
Trotter, Clyde P., Box 1881, El Paso, Texas

Wagner, William E., 1556 Hunter Ave., Columbus, Ohio
Walker, James T., 54 Orchard St., Painesville, Ohio
Wallis, Claud H., 127 U. S. Court House, El Paso, Texas
Watson, Reginald C., 2311 36th St., Galveston, Texas
Watt, Joseph T., Box 415, Laredo, Texas
Wayment, Elvin T., 631 E. 4th N. Logan, Utah
Webb, Alan G., 100 Custom House, Detroit, Mich.
Weinman, Carl J., 308 N. State St., Champaign, Ill.
Wene, George P., Dept. Ent., O. S. U., Columbus, Ohio
White, Richard O., Insecticide Testing Laboratory, Beltsville, Md.
White, Ralph T., 422 East Second St., Moorestown, N. J.
Williamson, John P., Box 301, Brownsville, Texas
Wolfe, Raymond F., Pleasantville, Ohio
Wood, J. Robins, c/o Box 1413, Mobile, Ala.
Woodbury, Charles G., 1739 H St., Washington, D. C.
Woodward, C. Gordon, 109 East Broadway, Louisville, Ky.

*List of Members Deceased in 1939*

George F. Arnold
W. E. Britton
R. N. Chapman
L. O. Ellisor
Fred W. Mally
E. A. Mechling
Stanislaw Minkiewicz
B. A. Osterberger
R. A. Vickery
Harold F. Willard

## COTTON STATES BRANCH

The fourteenth annual meeting of the Cotton States Branch of the American Association of Economic Entomologists was held in Tampa, Florida, on February 20, 21, 22 and 23, 1939. This meeting was held in conjunction with the fourth annual Florida Entomological Conference which is sponsored by the Newell Entomological Society. The attendance was the greatest in the history of the Branch, 166 having signed the attendance record.

A total of 57 papers were presented. These included treatises on pests of cotton, citrus, peach, grain crops, peanuts, livestock, sugar cane, corn, gladiolus, soy bean, forest products, and vegetables.

The Secretary-Treasurer reported receipts of $301.11 and expenditures of $123.65, with a balance of $178.46.

Oliver I. Snapp, Fort Valley, Georgia, was elected Chairman, L. L. English of Spring Hill, Alabama, Vice-Chairman and John T. Creighton, Gainesville, Florida, Secretary-Treasurer.

## NEWELL ENTOMOLOGICAL SOCIETY

The Fourth Florida Entomological Conference, sponsored annually by the Newell Entomological Society, was held in conjunction with the meeting of the Cotton States Branch of the American Association of Economic Entomologists. This meeting was held in Tampa, Florida, February 20 to 23, 1939, where the Newell Entomological Society and the Florida Entomological Society were co-hosts to the Cotton States Branch.

Displays at this meeting, assembled by members of the Newell Entomological Society, included the economic insects of Florida, insects of medical and veterinary importance, the butterflies of Florida, morphological drawings, copies of past Masters' theses, student insect collections retained by the department and other interesting material.

The newly elected officers of the society for the 1939–40 school term are: John Frederick, President; M. L. Anderson, Vice-President, R. M. Remington, Secretary; Jim Haeger, Treasurer; K. P. Bragdon, Reporter; and John T. Creighton, Faculty Advisor.

The society is supported by 52 members. This membership includes undergraduates, graduates and honorary members.

During the fall semester of 1939 the society has held bi-monthly meetings at which time campus or visiting speakers have appeared on the program.

JACK C. RUSSELL, *Secretary*

## FLORIDA ENTOMOLOGICAL SOCIETY

The annual meeting of the Florida Entomological Society was held at Gainesville, Florida, on December 8 and 9, 1939. This was one of the best attended meetings of the Society, there being 67 names on the register of attendance. During the sessions 17 papers dealing with a wide range of entomological subjects were presented and discussed.

The entomological dinner was held Friday evening with President J. H. Montgomery acting as toastmaster. An enjoyable after-dinner feature was a motion picture made in Mexico by Professor J. R. Watson.

At the business session the Society adopted a new constitution and by-laws by which it will be governed in the future. Herbert Spencer, U.S.D.A., Fort Pierce, Florida, was elected President for the coming year; Homer Hixson, University of Florida, Gainesville, Vice-President; A. N. Tissot, Agricultural Experiment Station, Gainesville, Secretary; and J. W. Wilson, Everglades Experiment Station, Belle Glade, Treasurer-Business Manager.

## PACIFIC SLOPE BRANCH

The twenty-fourth annual meeting was held at Stanford University, California, on June 27 to 29, 1939. This was undoubtedly the best meeting held so far, not only in attendance, which exceeded 200, but also in program. Fifty-eight papers were presented which covered every phase of entomology, including the experimental, taxonomy, teaching and demonstration. A motion picture was shown depicting the development of fog spraying, and a sound picture on the production and use of sulfur.

The outstanding feature of the meeting was a demonstration of spraying and dusting equipment. Eighteen different commercial companies and individuals participated and demonstrated spraying, dusting and fumigating apparatus, varying from hand machines to large power outfits capable of forcing an insecticide to the tops of trees 150 feet high and covering orchards at the rate of ten acres per hour. Much interest was shown in the demonstrations, not only by the entomologists, but also by members of other societies. Another notable feature of the meeting was the extensive exhibit of chemicals used for insecticides; mounts of injurious insects; insects, manuals and apparatus for class room use; models of cages, dusters and field and laboratory apparatus used in insect studies.

In place of the annual dinner, a barbecue was held out under the trees of the campus. H. M. Armitage presided, and called on several members for talks, including President E. R. Sasscer, S. A. Rohwer, E. O. Essig and R. W. Doane. The concluding meeting was a joint session with the Pacific Coast Entomological Society in the Academy of Science in Golden Gate Park, San Francisco.

Officers elected for the ensuing year were: Chairman, B. G. Thompson, Corvalis, Oregon; Vice-Chairman, H. L. Seamans, Lethbridge, Alberta, Canada; Secretary-Treasurer, Roy E. Campbell, Alhambra, California.

## EASTERN BRANCH

The Eastern Branch met in New York City on November 16 and 17, 1939, at the Hotel New Yorker. Dr. Clyde C. Hamilton presided over a program involving 36 papers, and a joint session with the National Pest Control Association involving 10 additional papers. Over two hundred attended the sessions.

Dr. E. R. Sasscer, President of the parent Association, addressed the members and spoke of plans for the Columbus meetings.

The financial report showed receipts of $4,440.40, and expenditures of $1,542.97.

W. H. White was elected Chairman, and J. L. Horsfall Vice-Chairman for the coming year.

EASTERN BRANCH MEDAL.—The jury consisting of H. N. Worthley, J. L. Horsfall and P. N. Annand selected the paper entitled "The Parasitic Castration of *Anasa tristis* Deg. by *Trichopoda pennipes* Fabr. and its Effect on Reproduction" as the best paper on this year's Eastern Branch program, and President E. R. Sasscer presented the award of a gold medal and seventy-five dollars to the author, Raimon L. Beard of the Connecticut Agricultural Experiment Station, New Haven, Connecticut, at the banquet in Columbus, Ohio.

## FINAL BUSINESS SESSIONS

### Friday and Saturday, December 29 & 30, 1939

The report of the Committee on Membership was adopted, and subsequently four names were voted upon separately that had not been presented to the Membership Committee for action. The vote for each was affirmative.

The report of the Committee on Resolutions was adopted and those resolutions are made a part of this report.

The Treasurer's report in the form of the Certified Public Accountant's audit was read and approved. This report went into more detail than heretofore, and with the exception of that part relating to those in arrears, is published herewith.

Professor O'Kane reported on the summer meeting to be held in Durham, and moved that a committee be appointed to look into the matter of the participation of this Association and report to the Executive Committee. This motion was seconded and carried.

It was moved by Mr. Burgess and carried that the Executive Committee be authorized to look into the matter of the publication of INDEX VI.

It was moved by Dr. Peairs that the Executive Committee be instructed to arrange the program so the final business session will be held before the final paper reading session if feasible. This motion was carried.

It was moved by Dr. Campbell that the Committee on Common Names of Insects be authorized and instructed to present with all new names and revisions of old names the reasons of members making these proposals and further that this Committee be authorized to comment on the proposals when it sees fit to do so. Carried.

REPORT OF THE SECRETARY ON THE 5 TO 10 YEAR SCHEDULE OF MEETING PLACES. The two entomological societies met and considered the ten-year schedule and set up the following five-year schedule subject to such changes by the Executive Committee as may be necessary: 1940 Philadelphia; 1941 San Francisco; 1942 New York; 1943 San Antonio; 1944 Chicago.

It is realized that under the constitution the time for the next annual meeting must be set by the membership or by the Executive Committee; it is hoped, therefore, that it will be possible to have a five-year program progressively before us throughout the years to come.

The second five-year period has been set up tentatively, and the complete ten-year schedule has been submitted to the American Association for the Advancement of Science in the hope that the schedule may crystallize their thought to the end that we may be meeting jointly at least in some of the years of the second five-year group: 1945 Atlanta; 1946 Toronto; 1947 Kansas City; 1948 Atlantic City; and 1949 Cincinnati.

It was moved by the Secretary, seconded and carried that the first five-year program be approved and that the second five-year program be approved tentatively subject to the action of the annual meeting in accordance with the constitution and subject to changes by the Executive Committee due to unforeseen contingencies.

At the conclusion of the business session President Sasscer made his concluding remarks which are reproduced herewith.

## REPORT OF THE RESOLUTIONS COMMITTEE

RESOLVED, That the thanks of the Association be extended to Neale F. Howard, T. H. Parks, D. M. DeLong, F. L. Campbell, J. N. Knull, Harold Waters, Alvah Peterson, R. A. Fulton and C. H. Kennedy, the Local Committee, for their efficient planning and excellent arrangements in connection with this, the Golden Jubilee Meeting of the Association, and that we express our grateful appreciation to the city and state officials, citizens, organizations, and the Ohio State University for their most unusual cooperation and courtesy.

RESOLVED, That this Association extend its thanks to the officers and members of the Entomological Society of America and to Dr. L.O. Howard for their participation in the SYMPOSIUM ON FIFTY YEARS OF ENTOMOLOGICAL PROGRESS, 1889-1939.

RESOLVED, That thanks of this Association be extended to the management of the Deshler-Wallick Hotel of Columbus for the accommodations and for the courtesies extended to our officers and members during our meetings.

RESOLVED, That in view of the interest shown in the instructive and inspirational exhibits at this meeting, prepared by various agencies, such appropriate exhibits be solicited as features of future meetings of the Association from entomological and commercial agencies.

RESOLVED, That entomologists in the field should keep in close contact with the various activities of conservation agencies in order that we may learn more about the effects of conservation measures on insect populations.

RESOLVED, That we keep definitely in mind that a reasonable proportion of research work should be carried in connection with the control activities in economic entomology.

WHEREAS, The progress in economic entomology during the last fifty years in North America has been enhanced by the cooperative efforts and support of entomologists of the Dominion of Canada, of the Republic of Mexico, and those of the various islands of the West Indies and of the United States,

BE IT RESOLVED, That this Association commend and endorse this spirit of cooperation.

WHEREAS, The long-time tests of natural and treated woods which have been conducted on Barro Colorado Island to determine resistance to attacks by termites have been of great value to entomologists the world over;

AND WHEREAS, The observations which various investigators have been able to make on insects under natural conditions because of the establishment of the station on Barro Colorado Island have developed information very valuable to entomologists;

AND WHEREAS, The observations made there on various species of fruit flies have greatly aided in establishing procedures to protect fruit cultures of our country from possible infestations of these pests;

AND WHEREAS, Numerous other examples of work which have been done there indicate the importance to economic entology of the continuation of this tropical research station;

THEREFORE, BE IT RESOLVED, That the American Association of Economic Entomologists expresses its gratification and commendation of the

effort that is being made to create a continuing charter for the research station at Barro Colorado Island, and

BE IT FURTHER RESOLVED, That this Association urge that such a charter be consumated as early as possible and that the Secretary be instructed to send a copy of this resolution to the Honorable Harry F. Byrd, Senator from Virginia.

Respectfully submitted,
J. B. MOORE
W. A. SHANDS
T. L. AAMODT
C. E. PALM, *Chairman*

## REPORT OF COMMITTEE ON PUBLICATIONS

Mr. President, Members of the Association:

The members of the Committee wish, first of all, to commend Dr. T. H. Frison, Editor of the JOURNAL OF ECONOMIC ENTOMOLOGY, for his excellent work in maintaining a publication of real merit. During the four years that Dr. Frison has been Editor of this publication, it has flourished and ranks high among entomological periodicals.

It is with real regret that the resignation of Dr. Frison is accepted. His resignation has become necessary because of ever increasing official duties and will take effect at the close of 1939. Dr. Frison has made a real sacrifice during these years and the Association owes him a deep debt of gratitude.

With the election of a new Editor at this meeting, the publications Committee can confidently assure the Association that the present high standards of the JOURNAL OF ECONOMIC ENTOMOLOGY will be maintained.

Compared with other scientific publications, the cost of producing the JOURNAL is low. The Editor's account shows a cash balance on hand of $2.53 as of December 22, 1939. The accounts of the Editor have been examined and the Committee finds them correct. The accounts of the Business Manager of the JOURNAL are covered by a separate audit.

In view of the fact that previous allocations have compelled the Editor and his staff to do many time-consuming routine tasks of which he should be relieved, the Committee recommends that a maximum sum of one thousand ($1000) dollars be allocated by the Association as a Journal Fund to be used by the Editor as needed for editorial, clerical and stenographic assistance and for any other items connected with the editing of the JOURNAL. This amount, which does not include the Editor's honorarium, represents a reasonable increase over previous allocations.

The Committee further recommends that as soon as the finances of the Association will permit, the present honorarium of $200 to the Editor be materially increased.

The Committee has placed nominations for Editor, Honorary Editor, Associate Editor and Business Manager in the hands of the Nominating Committee which will be reported at the proper time.

The Publications Committee
(Members present)
E. F. PHILLIPS
F. L. CAMPBELL
F. L. THOMAS
S. A. ROHWER
R. B. FRIEND
J. S. HOUSER
ROGER C. SMITH
W. B. HERMS, *Chairman*

## REPORT OF THE NOMINATING COMMITTEE

With one exception, and excluding the Editorial Board, the committee has worked on the idea that the officers or committeemen whose terms expire should not succeed themselves. The terms of the chairmen of six of the standing committees expire in 1939. For these committees the Nominating Committee had designated new chairmen.

President: Harry S. Smith
First Vice-President: W. A. Price
Vice-Presidents:
Pacific Slope Branch—B. G. Thompson
Cotton States Branch—O. I. Snapp
Eastern Branch—W. H. White
Plant Quarantine—George S. Langford
Apiculture—Frank R. Shaw
Extension—C. B. Dibble
Teaching—C. L. Metcalf
Executive Committee:
P. N. Annand. Term expires 1942
T. H. Frison. Term expires 1941
Committee on Common Names:
C. F. W. Muesebeck, Chairman. Term expires 1942.
Philip Garman. Term expires 1942
Committee on Membership:
C. L. Metcalf, Chairman. Term expires 1940
Albert Hartzell. Term expires 1942
George Maheux. Term expires 1943
W. D. Reed. Term expires 1944
Ralph H. Smith. Term expires 1945
Publication Committee:
A. B. Baird. Term expires 1944.
Charles H. Richardson. Term expires 1944
A. G. Ruggles. Term expires 1942
Joint Committee on Insect Collections:
Harold Morrison. Term expires 1942
Chairman to be from Entomological Society of America
Program Committee:
D. L. Van Dine, Chairman. Term expires 1941
L. S. McLaine. Term expires 1942
Committee on Codling Moth:
B. F. Driggers. Term expires 1942
James Marshall. Term expires 1942
Committee on Insecticide Terminology:
W. R. Horsfall. Term expires 1944
Joint Committee on the Promotion of Official Entomology:
George A. Dean, Chairman. Term expires 1940
F. N. Wallace. Term expires 1942
Committee on Popular Entomological Education:
P. D. Sanders, Chairman. Term expires 1942
J. H. Parks. Term expires 1943
Committee on Relation of Entomology to Conservation:
H. L. Seamans. Term expires 1942
Committee on Cooperation with Pest Control Operators:
Avery S. Hoyt. Term expires 1943
Board of Trustees of the Permanent Fund:
E. O. Essig. Term expires 1942
Nominee to Board of Governors of Crop Protection Institute:
W. P. Flint. Term expires 1942
Representatives on Council of Union of American Biological Societies:
S. B. Fracker. Term expires 1940
W. J. Schoene. Term expires 1940
Representative on Board of Trustees of Tropical Plant Research Foundation:
Herbert Osborn. Term expires 1940

Representative on National Research Council:
C. E. Palm. } Terms being July 1, 1940
James I. Hambleton. } and expire June 30, 1941
Councilor for the American Association for the Advancement of Science:
J. A. Hyslop. Term expires 1941
Editorial Board of the JOURNAL:
Editor—L. M. Peairs
Honorary Editor—E. P. Felt
Associate Editor—Harry B. Weiss
Business Manager—Ernest N. Cory
S. A. ROHWER, *Chairman*
ARTHUR GIBSON
J. S. HOUSER

## REPORT OF THE EXECUTIVE COMMITTEE

The Executive Committee in open session received the reports of the standing committees, the report of the secretary, and considered the tentative schedule of meeting places.

The Executive Committee also met with a committee of the Entomological Society of America to discuss and later to approve a five-year schedule of meeting places and a supplementary tentative schedule of five years.

The subject of a communication from Dr. J. L. King in regard to the time of meetings was discussed fully, no definite action being taken, but the difficulties in making such a change were pointed out.

The proposal that the Membership Committee be enlarged by the addition of two members, at least one of whom shall represent the Bureau of Entomology and Plant Quarantine, and the others, including the present members, shall be so distributed geographically that every section of the country will be represented, was approved.

The functions of the Committee on Popular Entomological Education were redefined to include the concept of active year-round publicity for the Association and for individual accomplishments, together with the coordination of the local publicity committee's work with that of this committee.

Our Representatives on the Union of Biological Societies were instructed to ascertain the objectives of the Union as a basis for consideration of possible contributions towards the expenses of the Union, and rejected the suggestions for the publication of a separate section dealing with the abstracting of entomological literature and likewise rejected the suggestion for the establishment of individual memberships as being not in conformity with our understanding of the original purpose of the Union.

The secretary was instructed to write a sympathetic letter to those members in arrears who are located in countries at war, and if no reply is received, to write off their indebtedness as uncollectible, without prejudice, in case they may want to be reinstated when conditions improve.

In recognition of the debt of gratitude the Association owes to the two editors, who have so ably developed the JOURNAL to its present excellent scientific and technical status, the Executive Committee voted to present a token of esteem to Dr. E. P. Felt and Dr. T. H. Frison.

Respectfully submitted by the Executive Committee

E. R. SASSCER — CLAY LYLE
E. N. CORY — J. J. DAVIS
A. F. BURGESS — HARRY S. SMITH
F. C. BISHOPP

## REPORT OF THE EXECUTIVE COMMITTEE MEETING, DECEMBER 30, 1939

The meeting was attended by President Sasscer, J. J. Davis, Clay Lyle and E. N. Cory. The Chairman for the Philadelphia meeting, selected after a conference with Dr. Mickel of the Entomological Society of America, C. H. Hadley is with J. A. G. Rehn and A. Glenn Richards as members. The balance of the committee is to be named by the Chairman. The Chairman for the San Francisco meeting selected by the Executive Committee, is W. B. Herms.

The matter of the editing of INDEX VI was then taken up in consultation with Dr. Felt, who stated that he was not anxious to do the work but if no one could be found to do the work, he would accept the task. The matter was held over pending word from Dr. Strong concerning the work of Miss Colcord, and it is hoped that it can be concluded in the near future.

## COMMITTEE APPOINTMENTS

The following appointments were made during the year by President E. R. Sasscer:

COMMITTEE ON NOMINATIONS:
S. A. Rohwer, Chairman; J. S. Houser, and Arthur Gibson.

COMMITTEE ON RESOLUTIONS:
C. E. Palm, Chairman, T. L. Aamodt, W. E. Shands, and J. B. Moore.

COMMITTEE ON ARRANGEMENTS:
Neale F. Howard, Chairman; D. M. DeLong and F. L. Campbell, Entertainment; T. H. Parks and J. S. Houser, Publicity; Alvah Peterson and R. A. Fulton, Equipment; and J. N. Knull and Harold Waters, Exhibits.

DELEGATE TO THE PACIFIC SCIENTIFIC CONGRESS:
P. N. Annand.

## CLOSING REMARKS OF PRESIDENT SASSCER

Before relinquishing the gavel the chair wishes again to express his appreciation of the confidence imposed in selecting him as your presiding officer for the year about to close. During my tenure of office it has been my privilege to attend all of the Branch meetings as well as those of the Texas Entomological Society, the Ontario Entomological Society, and the meetings of National Pest Control Association. These meetings were full of interest and it was my observation that the Branches were in a healthy condition. In brief, the parent Association may look with pride on the accomplishments of the various Branches which have set a high standard.

If the chair has in any way been able to contribute to the success and advancement of the Association, it has been due to the unstinted support and cooperation accorded by the membership as a whole and more particularly by the officers and members of the several committees. Special mention should be made, however, of the splendid cooperation of our Secretary, Dr. Ernest N. Cory, and the Chairman of the Committee on Arrangements for the Columbus Meeting, Dr. Neale F. Howard.

Unfortunately, Professor Harry S. Smith, our President Elect is not with us today and hence the usual practice of escorting him to the platform to receive the gavel will have to be waived. In selecting him for President during the forthcoming year the Association exercised good judgment and we may have every confidence that the affairs of the organization are in excellent hands.

In relinquishing the chair permit me to express my thanks for your patience with me in conducting these meetings and at the same time express the hope that all of you may experience a Happy and Prosperous New Year.

# OFFICIAL ROSTER

## AMERICAN ASSOCIATION OF ECONOMIC ENTOMOLOGISTS

**Organized 1889; Incorporated December 29, 1913**

## OFFICERS, 1940

| HARRY S. SMITH | W. A. PRICE | ERNEST N. CORY |
|---|---|---|
| Riverside, Calif. | Lexington, Ky. | College Park, Md. |
| *President* | *First Vice-President* | *Secretary* |

### Vice-Presidents

B. G. THOMPSON, Corvallis, Oregon (Pacific Slope Branch)
O. I. SNAPP, Fort Valley, Ga. (Cotton States Branch)
W. H. WHITE, Washington, D. C. (Eastern Branch)
GEORGE S. LANGFORD, College Park, Md. (Section of Plant Quarantine & Inspection)
FRANK R. SHAW, Amherst, Mass. (Section of Apiculture)
C. B. DIBBLE, East Lansing, Mich. (Section of Extension)
C. L. METCALF, Urbana, Ill. (Section of Teaching)

### Branch and Section Secretaries

ROY E. CAMPBELL, Alhambra, Calif. (Pacific Slope Branch)
J. T. CREIGHTON, Gainesville, Fla. (Cotton States Branch)
H. B. WEISS, Trenton, N. J. (Eastern Branch)
ROY G. RICHMOND, Washington, D. C. (Section of Plant Quarantine & Inspection)
W. A. PRICE, Lexington, Ky. (Section of Apiculture)
G. E. LEHKER, Lafayette, Ind. (Section of Extension)
ROGER C. SMITH, Manhattan, Kansas (Section of Teaching)

### Affiliated Organizations

FLORIDA ENTOMOLOGICAL SOCIETY

HERBERT SPENCER, *President*, Orlando, Fla.
A. N. TISSOT, *Secretary*, Gainesville, Fla.

NEWELL ENTOMOLOGICAL SOCIETY

JOHN FREDERICK, *President*, Gainesville, Fla.
JACK C. RUSSELL, *Secretary*, Gainesville, Fla.
JOHN T. CREIGHTON, *Adviser*

# STANDING COMMITTEES

### Executive Committee

HARRY S. SMITH, Riverside, Calif., *Chairman, Ex officio.*
ERNEST N. CORY, College Park, Md. *Ex officio.*
CLAY LYLE, State College, Miss. Term expires 1940.
J. J. DAVIS, Lafayette, Ind. Term expires 1940.
E. R. SASSCER, Washington, D. C. Term expires 1941.
T. H. FRISON, Urbana, Ill. Term expires 1941.
P. N. ANNAND, Washington, D. C. Term expires 1942.

### Committee on Common Names of Insects

C. F. W. MUESEBECK, Washington, D. C., *Chairman.* Term expires 1942.
CLAUDE WAKELAND, Denver, Colo. Term expires 1940.
T. E. SNYDER, New Orleans, La. Term expires 1940.
D. M. DELONG, Columbus, Ohio. Term expires 1941.
K. M. KING, Saskatoon, Sask., Can. Term expires 1941.
PHILIP GARMAN, New Haven, Conn. Term expires 1942.

### Committee on Membership

C. L. METCALF, Urbana, Ill. *Chairman.* Term expires 1940.
R. L. WEBSTER, Pullman, Wash. Term expires 1941.
ALBERT HARTZELL, Yonkers, New York. Term expires 1942.
GEORGE MAHEUX, Quebec, Can. Term expires 1943.
W. D. REED, Richmond, Va. Term expires 1944.
RALPH H. SMITH, Los Angeles, Calif. Term expires 1945.

### Publications Committee, Journal of Economic Entomology

W. B. HERMS, Berkeley, Calif. *Chairman.* Term expires 1940.
S. A. ROHWER, Washington, D. C. Term expires 1940.
F. L. CAMPBELL, Columbus, Ohio. Term expires 1941.
F. L. THOMAS, College Station, Tex. Term expires 1941.

E. J. NEWCOMER, Yakima, Wash. Term expires 1942.
A. G. RUGGLES, St. Paul, Minn. Term expires 1942.
J. S. HOUSER, Wooster, Ohio. Term expires 1943.
ROGER B. FRIEND, New Haven, Conn. Term expires 1943.
E. F. PHILLIPS, Ithaca, N. Y. Term expires 1943.
A. B. BAIRD, Belleville, Ont., Can. Term expires 1944.
CHARLES H. RICHARDSON, Ames, Iowa. Term expires 1944.

### Joint Committee on Insect Collections

R. H. BEAMER, Lawrence, Kan. Term expires 1940.
FRANKLIN SHERMAN, Clemson College, S. C. Term expires 1940.
E. C. VAN DYKE, Berkeley, Calif. Term expires 1941.
HAROLD MORRISON, Washington, D. C. Term expires 1942.
(Chairman to be from The Entomological Society of America)

### Program Committee

D. L. VAN DINE, Washington, D. C. *Chairman.* Term expires 1941.
GEORGE A. DEAN, Manhattan, Kan. Term expires 1940.
L. S. MCLAINE, Ottawa, Can. Term expires 1942.

### Committee on Codling Moth

B. A. PORTER, Washington, D. C. *Chairman.* Term expires 1940.
C. R. CUTRIGHT, Wooster, Ohio. Term expires 1940.
W. A. ROSS, Vineland Station, Ont., Can. Term expires 1941.
W. S. HOUGH, Winchester, Va. Term expires 1941.
JAMES MARSHALL, Vernon, B. C., Can. Term expires 1942.
B. F. DRIGGERS, New Brunswick, N. J. Term expires 1942.

### Committee on Insecticide Terminology

HARRY F. DIETZ, Wilmington, Del., *Chairman.* Term expires 1941.
C. M. SMITH, Washington, D. C. Term expires 1940.
F. L. CAMPBELL, Columbus, Ohio. Term expires 1942.
R. H. ROBINSON, Corvallis, Ore. Term expires 1943.
W. R. HORSFALL, Fayetteville, Ark. Term expires 1944.

### Joint Committee on the Promotion of Official Entomology

GEORGE A. DEAN, Manhattan, Kans. Term expires 1940.
T. J. HEADLEE, New Brunswick, N. J. Term expires 1941.
F. N. WALLACE, Indianapolis, Ind. Term expires 1942.

### Committee on Popular Entomological Education

P. D. SANDERS, Richmond, Va., *Chairman.* Term expires 1942.
R. R. REPPERT, College Station, Tex. Term expires 1940.
J. A. HYSLOP, Washington, D. C. Term expires 1941.
T. H. PARKS, Columbus, Ohio. Term expires 1943.

### Committee on Cooperation with Pest Control Operators

J. J. DAVIS, Lafayette, Ind., *Chairman.* Term expires 1940.
W. P. FLINT, Urbana, Ill. Term expires 1941.
AVERY S. HOYT, Washington, D. C. Term expires 1943.

### Committee on Relation of Entomology to Conservation

F. C. BISHOPP, Washington, D. C., *Chairman.* Term expires 1940.
T. H. FRISON, Urbana, Ill. Term expires 1941.
H. L. SEAMANS, Lethbridge, Alta., Can. Term expires 1942.

## TRUSTEES

### Board of Trustees for Permanent Fund

ERNEST N. CORY, College Park, Md., *Chairman. Ex officio.*
HARRY S. SMITH, Riverside, Calif. *Ex officio.*
ARTHUR GIBSON, Ottawa, Can. Term expires 1940.
A. F. BURGESS, Greenfield, Mass. Term expires 1941.
E. O. ESSIG, Berkeley, Calif. Term expires 1942.

### Trustees for Crop Protection Institute

P. J. PARROTT, Geneva, N. Y., *Chairman,* Term expires 1940.
W. C. O'KANE, Durham, N. H. Term expires 1941.
W. P. FLINT, Urbana, Ill. Term expires 1942.

# REPRESENTATIVES AND COUNCILORS

### Representatives on Council of Union of American Biological Societies

S. B. FRACKER, Washington, D. C. Term expires 1940.

W. J. SCHOENE, Blacksburg, Va. Term expires 1940.

### Representative on Board of Trustees of Tropical Plant Research Foundation

HERBERT OSBORN, Columbus, Ohio. Term expires 1940.

### Representatives to National Research Council

S. A. ROHWER, Washington, D. C. Term expires June, 1940.

Z. P. METCALF, West Raleigh, N. C. (Alternate). Term expires June 1940.

C. E. PALM, Ithaca, N. Y. Term begins July, 1940.

JAMES I. HAMBLETON, Beltsville, Md. Term begins, July 1940.

### Councilors for the American Association for the Advancement of Science

L. A. STEARNS, Newark, Del. Term expires 1940.

J. A. HYSLOP, Washington, D. C. Term expires 1941.

# JOURNAL OF ECONOMIC ENTOMOLOGY

### Editorial Board

L. M. PEAIRS, Morgantown, W. Va. *Editor.*

E. P. FELT, Stamford, Conn. *Honorary Editor.*

HARRY B. WEISS, Trenton, N. J., *Associate Editor*

ERNEST N. CORY, College Park, Md., *Business Manager.*

# MEMBERS, 1940

* Members who registered at 1939 meeting
** Life Members

Aamodt, T. L., Univ. Farm, St. Paul, Minn.*
Abbott, W. S., 23 Kenebee Ave., Takoma Park, Md.
Adair, H. S., Adair's Insect Control Service, Montgomery, Ala.
Adams, Eugene, Norman Park, Ga.
Alden, C. H., State Bd. of Ent., Cornelia, Ga.*
Alexander, C. C., 134 W. Ninth Ave., Columbus, Ohio.*
Alexander, C. P., State College, Amherst, Mass.
Algert, E. D., Box 1656, Nogales, Ariz.
Allen, H. W., Box H., Moorestown, N. J.
Allen, Norman, Pee Dee Expt. Sta., Florence, S. C.
Allen, Paul B., Jr., 820-B Washington St., Wenatchee, Wash.
Allen, R. H., Bd. of Agr., Boston, Mass.
Allen, Thomas C., Dept. of Ent., Univ. of Wisconsin, Madison.*
Alsterlund, John, Tobacco By-Products & Chemical Corp., Louisville, Ky.
Amos, John M., Ent. Dept., Univ. of Delaware, Newark.
Anderson, Bertram R., 3511 Bisbee St., El Paso, Tex.
Anderson, Edwin J., Pennsylvania State College, State College, Pa.*
Anderson, Lauren D., Truck Expt. Sta., Norfolk, Va.*
Anderson, O. G., Tobacco By-Products & Chemical Corp., Louisville, Ky.*
Anderson, William E., Dept. of Agr. & Immigration, Baton Rouge, La.
Anderson, William H., U. S. National Museum, Washington, D. C.*
Andre, Floyd, B.E.P.Q., Washington, D. C.*
Annand, P. N., B.E.P.Q., Washington, D. C.
Anthony, M. V., 12 Glenwolde Park, Tarrytown, N. Y.*
App, Bernard A., 4700 Music St., New Orleans, La.
App, Frank, Bridgeton, N. J.
Apple, James W., Dept. of Ent. & Zool., State College, Ames, Iowa.*
Arant, F. S., Auburn, Ala.
Armitage, H. M., Room 24, Agrl. Bldg., Embarcadero at Mission St., San Francisco, Calif.
Arnold, C. H., 414 E. 12th Ave., Columbus, Ohio.*
Arnold, Robert B., Tobacco By-Products & Chemical Corp., Richmond, Va.*
Arnold, Thomas A., 127 U. S. Court House, El Paso, Texas.
Arnott, Edward H., Arnott Exterminating Co., 247 Massachusetts Ave., Indianapolis, Ind.
Ashworth, John T., Danielson, Conn.
Asquith, Dean, P.O. Box 104, Mercedes, Tex.
Au, S., P.O. Box 3319, Honolulu, T. H.
Audant, Andre, Entomologist, S.N.P.A., Port au Prince, Haiti.
Avery, Paul C., Mission, Tex.

Babcock, O. G., Box 407, Sonora, Tex.
Back, E. A., B.E.P.Q., Washington, D. C.**
Badertscher, Amos E., 103 Bonnie Hill Rd., Burnbrae, Towson, Md.
Baerg, Wm. J., Fayetteville, Ark.*
Bailey, H. L., Dept. of Agr., Montpelier, Vt.
Bailey, J. L., P.O. Box 283, Greenfield, Mass.
Bailey, John W., Box 107, Univ. of Richmond, Richmond, Va.*
Bailey, Stanley F., Univ. Farm, Davis, Calif.
Baird, Alfred Briggs, 228 Dundas St. E., Belleville, Ont., Can.
Baker, Arthur C., Laboratorio Entomologico, Calzada Mexico-Tacuba 295, Col. Anahuac, Mex.
Baker, A. W., Ontario Agrl. College, Guelph, Ont., Can.
Baker, Howard, Box 424, St. Joseph, Mo.
Baker, Thomas J., 439 U. S. Court House, Portland, Ore.
Baker, William A., 1920 Parkwood Ave., Toledo, Ohio.

Baker, W. C., 8 Whippany Rd., Morristown, N. J.
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# New Insecticides and Spreaders on Shade Trees

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Gipsy Moth Sprays.—Despite the fact that arsenate of lead has been used for over forty years in great quantities for the control of the gipsy moth, *Porthetria dispar* L., for which insect this valuable insecticide was originally developed, there are problems constantly arising in regard to the application of this as well as other insecticides for the control of this major tree pest of New England.

To begin with, the gipsy moth caterpillar may be classed as one of the more difficult insects to control with arsenate of lead. Furthermore, the film of this poison must remain as a heavy residue on the foliage for a long period of time to maintain protection, particularly where there are migrations of caterpillars from nearby unsprayed trees. It is equally important that the film of arsenate of lead be uniform and adhere to the foliage as soon as drying of the water in the spray mixture takes place.

In addition, early spraying soon after the hatching of the eggs is necessary. At this time the young leaves of certain trees, particularly oaks, are small and may be covered with fuzz or down which disappears later but which at the time of spraying may interfere with the adherence of the spray material to the leaf. The effect of this down on the young foliage is to cause the spray to hang in droplets and either run off or be blown off by the wind. In other cases the young leaves may be unusually smooth, preventing a satisfactory adherence of the spray material.

Wetting Agents.—During 1937, 1938, and 1939, tests were conducted with a number of wetting agents incorporated in the arsenate of lead sprays for the purpose of reducing the surface tension of the spray so that the droplets would flatten out and penetrate the down mentioned above or spread over the smooth leaf where drying would take place with the adherence of the spray residue.

Among the wetting agents tested were cotton seed oil, a pine oil derivative,[1] *SSS* spreader (now known as *Filmfast*)[2] and the sodium salts of the alkyl ester of sulfosuccinic acid.[3] The last material is one of the most effective wetting agents known and, in a closely related form, has received considerable publicity in the newspapers, magazines and movies during the past year because of the striking demonstration of the application of this material to the feathers of a duck which results in the duck sinking in water and drowning.

*Vatsol OT, 10 per cent aqueous*, used in arsenate of lead sprays was found to produce the best wetting down of any of the materials tested with arsenate of lead through the fuzz of the young oak foliage. At the dilution of 1 to 1000 good results were obtained but at higher strengths too great a run-off of the spray resulted as a consequence of the greatly lowered surface tension.

This wetting agent appeared to solve the first part of the problem but it did not have the adhesive property which is necessary in a spray of this nature to maintain protection against the leaf feeders for the desired period of time. It was found that *Filmfast* at the rate of one-half pound to 100 gallons was compatible and resulted in satisfactory adherence of the arsenate of lead.

These results apply largely to applications made from moving spray rigs, as stationary spraying with this powerful wetting agent has a tendency to produce too great run-off and wastage even at the low concentration used.

It might be noted that where commercial spraying was done with this combina-

[1] *Palustrez B.*, manufactured by The Southern Pine Chemical Co., Box 389, Jacksonville, Florida.

[2] Received from Mechling Bros., Line St., Coopers Creek, Camden, N. J.

[3] *Vatsol OT, 10% aqueous*, the American Cyanamid Co., New York City.

tion there appeared to be a contact effect on the gipsy moth caterpillar from the wetting agent which led to tests to be mentioned later.

JAPANESE BEETLE SPRAYS.—Despite the ever increasing number of new sprays and insecticides offered each year for the control of the Japanese beetle, *Popillia japonica* Newm., in the final analysis it must be admitted that satisfactory control of this pest and complete protection from its ravages is an unsolved problem.

While arsenate of lead still remains the most effective spray for the control of the adult beetle, the danger of foliage injury on certain trees, such as the stone fruits, filberts, and even elms under certain climatic and soil conditions, may limit the application of this insecticide.

Tests with tetramethyl thiuram disulfide,[4] among other sprays, were conducted during the season of 1939; this proved to be the most effective repellent tested, giving protection from the Japanese beetle as long as it remained on the foliage which was until the first heavy rain washed it off. Repeated applications would increase the cost of spraying to a prohibitory point.

Tests with *Filmfast* as a sticker did not prove satisfactory in obtaining longer adherence under rainy conditions.

The possibility of the use of the new basic copper arsenate[5] for Japanese beetle control was considered but cage tests indicated that this material was less effective than standard arsenate of lead due to the fact that its killing effect was considerably slower and its repellent effect less.

CONTACT INSECTICIDES FOR YOUNG CATERPILLARS.—Control of the eastern tent caterpillar, *Malacosoma americana* F., is always a matter of popular interest and although arsenate of lead sprays give effective control, there are sometimes objections to its use and some tree owners desire a non-toxic insecticide.

Small scale experiments in southwestern Connecticut in the spring of 1939 indicated that control of very young caterpillars could be obtained by dusting with either cubé or very fine sulfur.

The fall webworm, *Hyphantria cunea* Drury, is a more important shade tree insect pest than the eastern test caterpillar and during 1939 was unusually abundant in southwestern Connecticut and in Westchester County, N. Y.

Here, again, is an example of an insect which may be readily controlled by an early spray of arsenate of lead, but later sprays with this insecticide for the control of a second brood are not desirable on fruit trees where fruit without a spray residue is desired.

Contact sprays for the control of the fall webworm have been rather unsatisfactory.

Cage tests comparing the effect of a widely used commercial Japanese beetle spray,[6] a powerful wetting agent[7] (the material mentioned in the gipsy moth caterpillar test) and a rotenone spray,[8] were conducted on two-thirds grown exposed caterpillars of the fall webworm during the past season with the following results. The Japanese beetle spray at 1 to 20 gave 37.5 per cent kill at the end of 13 days, the *Vatsol OT, 10 per cent aqueous*, at 1 to 20 gave 49.7 per cent kill at the end of 13 days, while the *Bonrote* spray at 1 pound to 10 gallons gave 67.7 per cent kill at the end of 13 days.

COLLOIDAL ARSENATES OF LEAD.—During the past few years, the so-called colloidal arsenates of lead have received considerable publicity. Tests with two types[9] were conducted with one or the other of these preparations during 1936, 1937, and 1938.

On some of the more arsenic-susceptible insects, such as young Eastern tent caterpillars, the spiny elm caterpillar, *Nymphalis antiopa* L., and oak sawfly larvae, colloidal arsenate of lead used at the rate of one pound to 300 gallons of water gave a kill that approximated control, as did ordinary arsenate of lead at the same dosage. For Japanese beetle and the fall cankerworm, *Alsophila pometaria* Harris, the low dosages were completely ineffective.

The conclusion was inescapable that the particle size of the lead arsenate affected toxicity to a relatively small extent. The lethal dosage of arsenate of lead remains practically the same whether the particle size is extremely minute or of

[4] Du Pont Japanese Beetle Spray, received from the Du Pont de Nemours Co., Wilmington, Del.

[5] Manufactured by the Sherwin Williams Co., Bound Brook, N. J.

[6] *Smack*, Lin-Tox Corp., Port Chester, N. Y.

[7] *Vatsol OT, 10% aqueous.*

[8] *Bonrote*, Bonide Chemical Co., Utica, N. Y.

[9] *Arsokoll*, Latter Laboratory, Inc., Manufacturing Chemists, 901 Elton Ave., Bronx, New York.
*Ledko*, Dye-Col Products, Inc., 565 Fifth Ave., New York.

ordinary size. The total amount of lead arsenate ingested by the insect is the important factor.

CARBOLINEUM SPRAY INJURES SUGAR MAPLE.—An imported carbolineum spray[10] has been used to some extent by gardeners and estate superintendents for control of red spiders on ornamentals. For several seasons small amounts of this material have been used on the laboratory grounds for the control of the spruce mite, *Paratetranychus ununguis* Jacobi, on arborvitae, and the oak red spider, *Tetranychus bicolor* Banks, on soft maple. The control obtained had been fair and the spray appeared to be perfectly safe under the conditions of application.

This season it was used on a block of sugar maples infested with a species of red spider, as yet undertermined. The effect of the infestation was to produce a brownish-green hue on the foliage which was quite conspicuous on the infested trees even at a distance.

The applications of carbolineum spray, for the control of this red spider, at the rate which had proven safe on soft maple produced severe burning of the sugar maple foliage. Subsequent tests on other sugar maples definitely proved that this spray is toxic to sugar maple foliage.

BASIC COPPER ARSENATE TESTS.—The new basic copper arsenate seemed to be a promising shade tree spray combining insecticidal and fungicidal qualities.

A considerable series of tests at the laboratories during 1939 showed that this material applied in advance of feeding by the black walnut caterpillar, *Datana integerrima* G. & R., the hickory tussock caterpillar, *Halisidota caryae* Harris, and the fall webworm gave protection from the attacks of these insects as well as a satisfactory control of the walnut leaf spot dsiease. On certain other pests it was not as effective, due to the fact that its killing properties were slower than those of arsenate of lead and also to the fact that some foliage injury was produced. Damage of the type usually produced by copper occurred on both fruit and foliage of McIntosh and Cortland apple trees, and arsenical injury developed on filbert foliage which received the drift and drip from the sprayed black walnuts mentioned above.

While no foliage injury occurred on silver maple, red maple, sugar maple, pin oak, butternut, black walnut, white oak, hybrid chestnut, and shagbark hickory, forsythia and lilac underneath the trees showed marginal burning characteristic of arsenical injury.

On olene caterpillars, probably *Olene achatina* S. & A., the action of copper arsenate was very slow compared with arsenate of lead although the latter gave only fair control at ordinary strengths. The olene caterpillar is apparently quite as resistant as the gipsy moth caterpillar.

TESTS WITH SALTS OF DINITRO-CRESYLATE.—Tests with *Elgetol*[11] as an orchard spray have been very favorably reported upon by entomologists during the past two years and tests with this material as a shade tree spray have been given attention during the past season.

Applied as a delayed dormant spray for the control of the eggs of the spruce red mite on Norway spruce, European red mite, *Paratetranychus pilosus* C. & F., on apple, the spruce gall aphid, *Adelges abietis* L., on Norway spruce, and the oyster shell scale, *Lepidosaphes ulmi* L., on willow, *Elgetol* resulted in good control of these pests with no injury to the trees where applied at a strength of 1 per cent.

At the strength of 1½ per cent, excellent control was obtained of the oyster shell scale (eggs) on lilac, 95 per cent control of the San Jose scale, *Aspidiotus perniciosus* Comst., on purple plum and 50 per cent control of the partly grown tulip tree scale, *Toumeyella liriodendri* Gmel., on tulip tree. No spray injury was observed in any of these tests, but apparently the bright yellow color of *Elgetol* may be a detriment to its use around white or light-colored painted buildings, while the men who did the spraying complained of the spray staining their hands yellow.

It is evident from the above that spraying to control insects on shade and ornamental trees presents problems quite different from those in commercial fruit orchards. In addition to the greater susceptibility of foliage of some ornamentals to spray injury, the situation is further complicated by the necessity of spraying near buildings which limits spray materials to those which can be used with safety around painted surfaces.—11-16-39.

[10] *Carbo-Spray*, received from the Half Moon Manufacturing and Trading Co., Inc., 120 Liberty St., New York.

[11] A salt of dinitro-cresylate and other ingredients, manufactured by Standard Chemical Products, Inc., Hoboken, N. J.

# *Scolytus sulcatus* Lec. Transmits Dutch Elm Disease Fungus Under Controlled Conditions[1]

W. D. Buchanan, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

In an article on the biology of *Scolytus sulcatus*, Pechuman (1938) states that apple is probably the usual host of the beetle, but that it also breeds in elm, plum, peach, and mountain ash. He indicates that the species occurs in parts of New York, Connecticut, and New Jersey. In a foreword to this article Donald L. Collins states that *S. sulcatus* has been observed in several locations in Westchester County, N. Y., under circumstances such as to arouse suspicion that, in specific instances, it may have been the agent of transmission of the Dutch elm disease fungus (*Ceratostomella ulmi* (Schwarz) Buisman).

As early as 1933 the writer suspected that *Scolytus sulcatus* might transmit the fungus, because at that time a dead adult was found in a diseased elm tree at Chatham, N. J. In 1934 several females were found ovipositing in a diseased elm tree at Montclair, N. J. In 1938 C. W. Collins and R. T. Webber, of the Morristown, N. J., laboratory, found *S. sulcatus* and *S. multistriatus* Marsh. ovipositing at Hyde Park, N. Y., in a branch that had broken from an elm tree not known to be diseased. The branch was free of general discoloration but the fungus was isolated from streaks that extended from some of the beetle galleries. *C. ulmi* was also isolated from one of 10 *S. sulcatus* adults and from one of 21 *S. multistriatus* that were taken from this branch. In 1939 the fungus was isolated from two of 20 *S. sulcatus* beetles that issued from a section of a chemically killed elm that the writer found at Vernon, N. J. During the same year 39 *S. sulcatus* and 44 *S. multistriatus* were taken from their oviposition galleries in a single elm trap tree at Naughright, N. J. When these beetles were cultured *C. ulmi* was isolated from three of the 44 *S. multistriatus* but from none of the *S. sulcatus*.

Although *Scolytus sulcatus* has been found breeding in elm on several occasions by members of the Morristown laboratory, it is by no means abundant in elm. The writer has examined certain areas where it occurred in elm and has found decadent apple trees in the vicinity in which the species was breeding. The beetles found in the elm probably came from the apple trees.

Transmission Experiments.—In 1938 some preliminary experiments were conducted with *Scolytus sulcatus* reared from apple. These beetles were artificially contaminated in May and June by forcing them to walk over a culture of *Ceratostomella ulmi* growing on potato-sucrose agar in a Petri dish. The contaminated beetles were then liberated on six elm trees (average of 33 beetles per tree) enclosed in cheese-cloth cages. The trees were 5 year old nursery stock which had been transplanted to butter tubs in 1937. When the beetles were removed from the trees, it was found that they had made an average of 61 injuries per tree, 58 per cent of which were in the twig crotches and the remainder in the trunks. (Injury as used here refers to an instance in which the beetles penetrated the bark and reached the sapwood. Reference is made to the number of injuries per tree because the chances for infection would seem to increase with the number of injuries that are made by a given percentage of infective beetles.) Typical symptoms of the Dutch elm disease developed in three of the six trees, and *C. ulmi* was isolated from them. No attempt was made to culture the other three trees, which showed no symptoms of the disease.

In June 1939 the work with artificially contaminated *Scolytus sulcatus* was repeated. In one experiment 49 beetles, on an average, were liberated on each of five nursery elm trees enclosed in cheese-cloth cages. The injuries made by the beetles averaged 105 per tree and 90 per cent of these were in the twig crotches. *Ceratostomella ulmi* was isolated from two trees in which typical disease symptoms developed. In a second experiment arti-

[1] The writer is indebted to C. W. Collins, in charge of the Morristown, N. J., laboratory of the Bureau of Entomology and Plant Quarantine, for assistance and suggestions. The assistance of C. S. Moses of the Bureau of Plant Industry is also greatly appreciated. He supplied the cultures of *Ceratostomella ulmi* used to contaminate the beetles and determined whether or not the fungus was present in the trees and beetles referred to in this paper.

ficially contaminated *S. sulcatus* beetles were liberated into a screened cage that contained both elm and apple logs as well as 10 elm and 2 apple trees. There was an average of 96 injuries per elm tree, 95 per cent of which were in the twig crotches, and an average of four injuries in the apple trees, 88 per cent of which were in the twig crotches. It should be mentioned that the apple trees were much smaller than the elms and therefore offered less surface for attack. The beetles oviposited in both the elm and the apple logs. No attempt was made to ascertain how many galleries they formed or whether *C. ulmi* became established in them. Two of the 10 elm trees developed typical symptoms of the Dutch elm disease. *C. ulmi* was later isolated from these two trees and from one of the two apple trees.

It should be mentioned that there were no external symptoms of the Dutch elm disease in the apple tree referred to above. However, there were in the wood narrow streaks of discoloration which extended as much as 3 inches from the injuries. It was from one of these streaks of discoloration that the fungus was isolated. According to unpublished notes, S. J. Smucker, of the Bureau of Plant Industry, has demonstrated that *Ceratostomella ulmi* will spread to the crown of an apple tree when inoculations are made in the base. He also found that in sections taken from inoculated apple trees and stored in deep shade the fungus was viable for almost a year.

In June 1938, sections were obtained from a diseased elm tree. In these sections there was a complete ring of discoloration, caused by *Ceratostomella ulmi*, flush against the bark. Adult *Scolytus sulcatus* beetles were confined with these logs in muslin-covered glass jars and oviposition was obtained. The material was kept in an outdoor insectary until May 1939, when each section was placed in a cheesecloth cage containing a healthy nursery elm tree. The beetles emerged in June and fed at will on the trees. They made, on an average, 87 injuries per tree, 84 per cent of the injuries being in the twig crotches. Typical symptoms of the disease developed in three of the four trees, and *C. ulmi* was isolated from them. These trees showed a higher percentage of infection than trees fed upon by artificially contaminated *S. sulcatus*, but both tests are too limited to permit any conclusions to be drawn from them.

In 1939, sections of elm trees that had been killed with dry copper sulfate, at Vernon, N. J., were brought to the Morristown laboratory. These sections contained living *Scolytus sulcatus* larvae hibernating in the wood. Reference has previously been made to the fact that *Ceratostomella ulmi* was obtained from two of 20 beetles that issued from this material. On an average 29 of the beetles that issued in June were liberated on each of four healthy nursery elms enclosed in cheesecloth cages. These beetles made an average of 49 injuries per tree, 89 per cent of which were in the twig crotches. All four trees were cultured but *C. ulmi* was isolated from only one of them. However, this tree did not develop any symptoms of the Dutch elm disease, and the fungus was isolated from the vicinity of only one of the two injuries which were cultured.

SUMMARY.—*Scolytus sulcatus* occurrs in parts of New York, Connecticut, and New Jersey. Apple is probably the usual host, though it breeds in elm, plum, peach, and mountain ash. Although the species has been found attacking elm to a limited extent only it has been suspected of transmitting the Dutch elm disease fungus (*Ceratostomella ulmi*) in certain instances.

*Scolytus sulcatus* has been found in elms affected by *Ceratostomella ulmi* and the fungus has been isolated from beetles found in and issuing from elm material collected in the field.

Beetles artificially contaminated with *Ceratostomella ulmi* inoculated elm and apple trees under controlled conditions. Elm trees were also inoculated and infected when fed upon by beetles issuing from diseased elm wood.

Although the experiments show that *Scolytus sulcatus* is capable of transmitting *Ceratostomella ulmi* under controlled conditions, there is as yet no proof that it is responsible for elms becoming infected with *C. ulmi* in nature.—11-16-39.

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# Control of Aquatic Midges with Notes on the Biology of Certain Species

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INTRODUCTION.—The results of laboratory and field investigations and of actual field operations for the control of certain species of the family Chironomidae, commonly known as midges, are reported in this paper.

The investigations and control operations were conducted at the site of the New York World's Fair. The operations resulted in very effective control. Since the time available for the investigations was not sufficient to solve all of the variety of problems encountered, the methods evolved and results obtained are presented not as the best solution of such a problem under all conditions but rather as a successful example of control in one situation.

The creation during 1936 and 1937 of two fresh-water lakes, high in organic content, on what had previously been salt marsh meadow open to tidal action had, apparently, created optimum conditions for the breeding of certain species of chironomids and, as a result, midge adults were present in enormous numbers near the shores of Fountain and Willow Lakes within the World's Fair site during the summer of 1938. It was imperative that a very considerable reduction in the number of these midges be effected before April 30, 1939, the opening date of the Fair, and that the control thus effected be continued throughout the duration of the Fair.

These studies were begun in July, 1938, and were conducted as a cooperative effort on the part of the New York City Department of Health and the New York World's Fair Corporation. The Health Department made available services of a trained entomologist on a full-time basis while the Fair Corporation supplied the other personnel and the apparatus and materials necessary for the investigational and control work.

SPECIES PRESENT.—The following species of Chironomidae were taken on the wing in the vicinity of the lakes, or were bred in the laboratory from larvae or eggs taken from the lakes (determinations by Dr. Alan Stone).

*Chironominae*

*Chironomus lobiferus* Say
*Chironomus cingulatus* Mg.
*Chironomus tenuicaudatus* Mall.
*Chironomus* sp. near *tenuicaudatus* Mall.
*Chironomus brachialis* Coq.
*Chironomus nervosus* Staeg.
*Chironomus* sp. near *nervosus* Staeg.
*Chironomus* sp. near *paganus* Mg.
*Chironomus decorus* Joh.
*Tanytarsus eminulus* (Walk.)?

*Tanypodinae*

*Procladius culiciformis* (L.)
*Procladius choreus* (Mg.)
*Tanypus puntipennis* Mg.

Of these, *C. lobiferus*, *C. cingulatus*, and *C. tenuicaudatus* were the dominant species present; the first two were extremely abundant throughout the breeding season while the third species became most abundant during the latter part of the season. *P. culiciformis*, *P. choreus*, and *T. punctipennis* were quite abundant over the entire period.

Of the list of species given above, *T. eminulus* and *Chironomus* sp., near *paganus*, were the only ones which did not produce adults in the laboratory from material taken from various portions of the lakes. The former species became moderately abundant on the wing during the later part of the breeding season; only one specimen of the latter species was taken on the wing in mid-October.

*C. brachialis* was noted on the wing in moderate numbers during late August; adults emerged in moderate numbers in the laboratory, with a particularly heavy emergence during the latter part of September. Only one specimen of *C. decorus* emerged in the laboratory.

DESCRIPTION OF THE BREEDING AREA.—The New York World's Fair site is situated on what was originally two distinct areas: the Corona Dump which had been built up through many years of dumping of the various types of urban refuse, and the Flushing Meadow, a salt marsh through which Flushing Creek meandered.

Flushing Meadow was, in effect, a valley surrounded on three sides by steeply rising uplands and open on the fourth side to Flushing Bay. During periods of high tide Flushing Creek carried sea water into the meadow; during the monthly high tides the meadow was generally flooded. During low tides Flushing Creek carried out to the bay the fresh water which drained into the valley from the surrounding uplands and which flowed from a number of underground wells near the southern end of the meadow. In addition to the fresh water drainage, a rather considerable amount of raw sewage flowed into the meadow or directly into Flushing Creek. The meadow had been ditched several years previously to control mosquito breeding.

One of the first steps taken in preparing this site for the World's Fair was to dredge out two portions of the salt marsh so as to create two relatively shallow lakes. The dredging was performed rather irregularly, so that the depth of the resulting lakes was quite variable, ranging from three to about eighteen feet, the greatest depths being those along the old creek channel. In a large number of places the dredging did not penetrate below the salt marsh sod. The marsh areas around the larger lake and around about one-half the smaller lake were filled in with the dredged material and with material from the Corona Dump. The remaining marsh area around the smaller lake remained unfilled.

Flushing Creek was shut off from the bay by tide gates and, as a result, the water in the lakes rapidly became fresh. The raw sewage continued to flow into the lakes for some time after their establishment, but this condition was remedied before the opening date of the Fair by the construction of sanitary sewers.

The two lakes thus created extend over approximately 150 acres, and store about 260 million gallons of water, when maintained at a level of 1.5 feet above mean low tide.

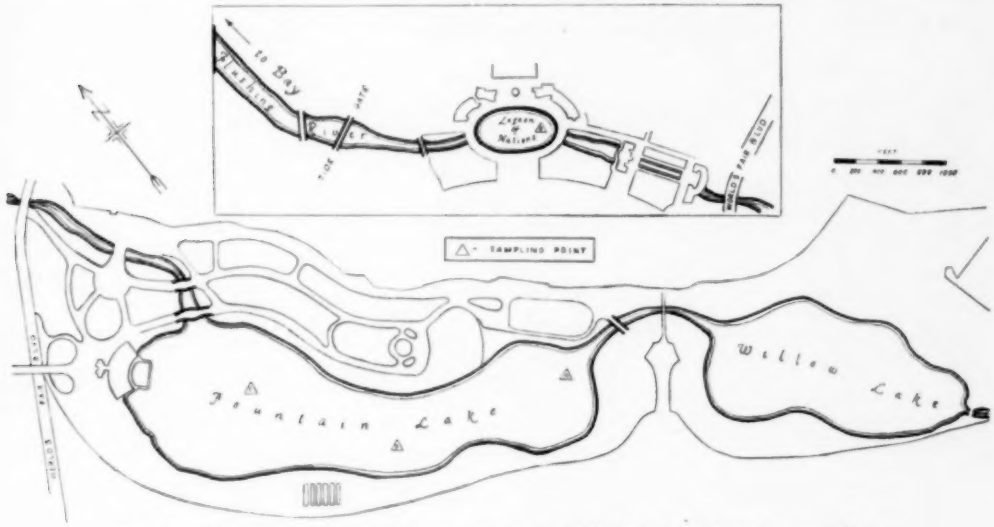


FIG. 1.—Map of midge breeding area at the World's Fair Site showing sampling points for analysis of lake water.

BIOLOGICAL NOTES.—It is not surprising that the lakes offered very favorable conditions for the breeding of a number of chironomid species and that midge adults were soon present in enormous numbers.

The organic matter originally present on the bottom (the salt marsh sod) began decomposing as soon as it was flooded. The raw sewage flowing into the lakes added to the organic content. A goodly amount of the fertilizer which was applied on the shores soon was washed into the lakes.

In the shallow lakes the water at the bottom became quite warm during the summer months, and decomposition proceeded rapidly. The products of decay taken up by the water supported the

growth of various organisms which, together with the organic matter itself, formed an abundant supply of food for the chironomid larvae.

An analysis of four samples of water taken at varying depths from different portions of the lakes during the middle of May, 1938 is presented in table 1. The water was decidedly green and turbid due to heavy growth of microscopic organisms at that time. Another sample of the water taken during the middle of June contained 4000 units of *Cyclotella*. An extremely heavy concentration of minute green algae suspended in the water appeared late in August and lasted until the end of September. These proved to be *Scenedesmus*, *Ankistrodesmus*, *Selenastrum* and *Chlorella*. The heavy growth of these organisms was undoubtedly accentuated by the high nitrogen values and by the shallow depth of the lakes.

**Table 1.—Analysis of lake water (May, 1938).**

| Analyses | Sample* A | B | C | D |
|---|---|---|---|---|
| PHYSICAL EXAMINATION | | | | |
| Turbidity (p.p.m. Silica) | 22 | 25 | 25 | 165 |
| Color (p.p.m. Platinum) | (green color due to micro-organisms) | | | |
| Odor | 3 g. | 3 g. | 3 g. | 3 g. |
| CHEMICAL EXAMINATION | | | | |
| Albuminoid ammonia (p.p.m. Nitrogen) | 0.820 | 2.900 | 3.200 | 1.340 |
| Free ammonia (p.p.m. Nitrogen) | 0.840 | 2.700 | 4.800 | 2.260 |
| Nitrite (p.p.m. Nitrogen) | 0.140 | 0.600 | 0.600 | 0.300 |
| Nitrate (p.p.m. Nitrogen) | 0.50 | 1.70 | 1.70 | 1.60 |
| Total solids (p.p.m.) | 850 | 1242 | 1308 | 1448 |
| Chlorine (p.p.m.) | 250 | 452 | 470 | 430 |
| Hardness (p.p.m. $CaCO_3$) | 250 | 340 | 350 | 340 |
| Alkalinity (p.p.m. $CaCO_3$) | 154 | 214 | 222 | 228 |
| Iron (p.p.m.) | 1.60 | 0.60 | 0.90 | 14.00 |
| Total lime (p.p.m. $CaCO_3$) | 124 | 172 | 174 | 186 |
| Total magnesium (p.p.m. $CaCO_3$) | 126 | 168 | 176 | 154 |
| Hydrogen ion (pH) | 8.5 | 8.7 | 8.7 | 8.3 |
| MICROSCOPICAL EXAMINATION | | | | |
| Total organisms, standard units per c.c. | 4230 | 3350 | 2770 | 3080 |
| Amorphous matter | 3000 | 4000 | 3400 | 30,000 |
| Coccus | 1000 | 1000 | 1000 | 1000 |
| Aphanizomenon | 350 | 650 | 500 | 600 |
| Clathrocystis | 2000 | 1200 | 850 | 1300 |
| Euglena | 300 | — | — | — |

* Sample A taken at depth of 4½ ft. Sample B taken at depth of 5 ft. Sample C taken at depth of 4 ft. Sample D taken at depth of 2 ft. See Figure 1 for sample sources.

The effect of water pollution, or of a high organic content in water, on chironomid breeding has been noted by a number of investigators. Richardson (1921) found that due to increasing pollution southward in the Illinois River, there occurred an enormous increase in larval Chironomidae, with the invasion of several more or less pollutional species. In the channel of the river, about 150 miles south of Lake Michigan, he found (average valuations per acre) 0.2 pounds of chironomid larvae in 1915 and 182 pounds in 1920. About 50 miles farther below Lake Michigan he found no chironomid larvae in the channel in 1915 and 164 pounds per acre in 1920.

Branch 1923 found *C. cristatus* F. (*C. militaris* Joh.?) breeding profusely in a stream into which a milk plant poured its waste. Sadler (1935) found larvae of *C. tentans* F. in greatest abundance in stagnant water where there was a good deal of pollution, as in ponds or basins treated with various kinds of fertilizers. Weston and Turner (1917) state that *C. decorus* was one of the organisms commonly found in the polluted part of the stream they investigated. Embody and Sadler (1934) noted that midges of the genus *Chironomus* were attracted to a pond a day or so after the addition of fertilizer thereto, and deposited enormous numbers of eggs. The breeding of chironomids in activated sludge plants for the treatment of sewage led Buchmann

(1932) to investigate methods of control.

Although too great a degree of sewage pollution will exert a deterrent effect upon chironomid breeding, the tolerance of the larvae of some species is indicated by the report of a survey of the Sangamon River by Jewell (1919). Starting at Decatur, the source of the sewage pollution, no chironomid larvae were found in samples taken 1, 6, 20, 30, 35 and 39 miles downstream. At the last point the water showed just a trace of dissolved oxygen, the pH was 7.6, the appearance was dark and slaty and the odor was septic. A sample taken 50 miles below Decatur contained chironomid larvae. At this point the water contained 0.3 p.p.m. dissolved oxygen (3% of saturation), the pH was 7.8, the appearance was milky and the odor was less pronounced. At points 60 and 70 miles below Decatur, chironomid larvae were found in the bottom despite the fact that the dissolved oxygen had dropped off to zero at both these points. Thereafter chironomid larvae were found in four of the five samples taken above Springfield, at ever increasing distances from Decatur.

ECOLOGICAL DISTRIBUTION OF LARVAE.—A knowledge of the larval habitats of the various species present in the lakes was, of course, of particular importance in evaluating possible methods of control.

A number of authors have commented on the ecological distribution of the larvae of the various chironomid species. Richardson has shown that certain species of Chironomidae prefer a strongly pollutional habitat, while other species are tolerant or indifferent, and still others are confined to cleaner water. Kolkwitz and Marsson (1909) have made similar reports and assign the red species to the zones of greater decay, the yellow ones to the oligosaprobic regions. Goetgheuber, (1911) established the larvae of the genus *Chironomus* into three groups based on their external structures. The larvae of his groups II and III (in which the branchial filaments of the eleventh segment are lacking) had been found living in the parenchyma of submerged leaves of numerous aquatic plants. The larvae of his *Chironomus* Group I (which bear two pairs of branchial filaments on the ventral side of the eleventh segment) have been found abundant at a depth of 65 ft. and rare to an extreme depth of 325 ft.

**Table 2.—Proportions of the various species found in three typical samples of larval habitat in Fountain Lake.**

| | Samples | | | | | |
|---|---|---|---|---|---|---|
| | Dense mat of algae scraped from underwater portions of a raft floating in the lake | | Marsh sod and gray clay from lake bottom at depth of 3 feet | | Black sludge and decaying vegetation from lake bottom at depth of 5 feet | |
| Species | Number Emerged | Per Cent of Total | Number Emerged | Per Cent of Total | Number Emerged | Per Cent of Total |
| *Chironomus lobiferus* | 87 | 47 | 82 | 82 | 14 | 36 |
| *C. cingulatus* | 11 | 6 | 6 | 6 | 18 | 46 |
| *C. tenuicaudatus* | 72 | 39 | 0 | — | 2 | 5 |
| *C. nervosus* | 6 | 3 | 0 | — | 0 | — |
| *C. sp. near nervosus* | 8 | 4 | 0 | — | 1 | 3 |
| *C. decorus* | 0 | — | 0 | — | 1 | 3 |
| *C. brachialis* | 1 | 1 | 0 | — | 0 | — |
| *P. choreus* | 0 | — | 12 | 12 | 2 | 5 |
| *Tanytarsus* sp. | 0 | — | 0 | — | 1 | 3 |

In order to determine the relative proportions of the various species in some of the typical ecological environments present in the lakes under investigation, three samples of larval habitat were removed, more or less intact, from the lakes and established in the laboratory. Sample 1 consisted of a dense mat of algae scraped from the underwater portions of a wooden raft floating in the water, sample 2 consisted of a quantity of marsh sod and gray clay from the lake bottom at a depth of three feet, and sample 3 consisted of a quantity of black sludge and decaying vegetation from the lake bottom at a

depth of five feet. Midge adults from the three samples were preserved and identified. The results are presented in table 2.

In addition a number of other samples were brought into the laboratory, where the larvae contained in each were identified and counted. The results are presented in table 3.

Based upon these results as well as upon an extended series of observations in the field, the distribution of the larvae of the species found breeding in the lakes may be summarized as follows:

*C. tenuicaudatus* larvae were found almost exclusively amongst green algal filaments in shallower portions of the lake, or otherwise near the surface of the water where dissolved oxygen, temperature and intensity of light would be relatively high. Only occasionally were specimens found at greater depths. The larvae of this species are yellowish-orange in color, and possess no respiratory processes other than the anal gills. The larvae of *C. nervosus* and a species near *nervosus* were also almost restricted to this type of environment. *C. brachialis* larvae, which are dark red mottled with green, and which bear no respiratory processes other than the anal gills, were in all cases discovered only in an environment of this sort.

*Chironomus lobiferus* larvae were found to be more tolerant; they were present abundantly in all parts of the lake bottom except in the black sludge at the greater depths. These larvae are dark red, occasionally with green mottling, and bear a gill-like process on each latero-posterior margin of the eleventh segment.

The larvae of *Procladius* sp. and of *Tanypus* sp. were found distributed over the lake bottom in locations similar to those of *lobiferus* with the exception of the cleaner or shallower areas, where they were rarely encountered. They were relatively more abundant in black sludge bottoms than were *lobiferus*. The *Procladius* larvae are yellow and possess four anal gills, while those of *Tanypus* are pinkish and possess six anal gills.

*Chironomus cingulatus* larvae were the most tolerant of those present in the lakes. This was the only species found in the black sludge bottom at depths of seven feet or more. The single specimen of *C. decorus* bred from lake material also came from a black sludge bottom. The larvae of *cingulatus* are bright red and bear two pairs of long branchial filaments on the ventral side of the eleventh segment; the larvae of *C. decorus* also possess two pairs of branchial filaments.

In terms of the association of species

**Table 3.—Species present in various types of bottom at different depths in Fountain Lake.**

| SAMPLE | TYPE OF BOTTOM | DEPTH | SPECIES PRESENT |
|---|---|---|---|
| 1 | Gravel, sand, and ashes | 1½ ft. | *C. lobiferus* |
| 2 | Marsh turf | 2 ft. | *C. lobiferus* |
| 3 | Gray clay and decaying vegetation | 2½ ft. | *C. lobiferus* |
| 4 | Black sludge and decaying vegetation | 3½ ft. | *C. cingulatus*<br>*C. lobiferus*<br>*Procladius* sp. |
| 5 | Black sludge | 3½ ft. | *C. cingulatus*<br>*Procladius* sp.<br>*Tanypus* sp. |
| 6 | Black sludge | 3½ ft. | *C. cingulatus*<br>*C. cingulatus* |
| 7 | Black sludge, gray clay, and decaying vegetation | 4 ft. | *C. lobiferus*<br>*Procladius* sp. |
| 8 | Sand and ashes mixed with decaying vegetation | 4 ft. | *C. cingulatus*<br>*C. lobiferus*<br>*Procladius* sp. |
| 9 | Gray clay | 5 ft. | *C. cingulatus*<br>*C. lobiferus*<br>*Procladius* sp. |
| 10 | Black sludge and gray clay | 7 ft. | *C. cingulatus* |
| 11 | Black sludge and decaying vegetation | 9 ft. | *C. cingulatus* |
| 12 | Black sludge covered with greenish slime | 11 ft. | *C. cingulatus* |
| 13 | Black sludge covered with greenish slime | 18 ft. | none |

(Table 2), *C. lobiferus* and *C. tenuicaudatus* were co-dominant amongst chlorophyll-bearing plants several inches below the surface of the water with *C. cingulatus* *C. nervosus*, a species near *nervosus* and *C. brachialis* also present. In decomposing marsh sod and gray clay three feet under the surface of the water, *C. lobiferus* was the dominant species with *P. choreus* and *C. cingulatus* also present. In black sludge and decaying vegetation at a depth of five feet, *C. cingulatus* and *C. lobiferus* were co-dominant. At greater depths *C. cingulatus* became the dominant species.

EGGS.—The gelatinous egg masses of *C. lobiferus* and *C. cingulatus* were found at or just below the surface of the water attached to a variety of materials such as barges or boats, stones, rope or cable, aquatic vegetation projecting above the surface of the water, and even to some freshly creosoted planking which extending into the water. The egg masses of both species are cylindrical in shape, and the tan or brownish eggs therein follow a definite pattern. The egg sacs of *lobiferus* are 8 to 18 mm. in length and 2 to 3 mm. in diameter; those of *cingulatus* are 16 to 25 mm. in length and about 3 mm. in diameter. Counts of the eggs in a number of undifferentiated egg masses of these species showed an average of 1768 eggs per mass.

The egg masses of *C. tenuicaudatus* are similar to those of the above species but only about one-half the size of those of *C. lobiferus*.

*Procladius* sp. egg masses were generally found lying on the lake bottom. The masses are more or less spherical in shape and are 3 to 5 mm. in diameter. The eggs seem to follow a rather irregular pattern.

Eggs deposited in the laboratory by *C. cingulatus* females hatched after 42 to 72 hours; the average time was 58 hours.

RESISTANCE OF EGG MASSES TO DESICCATION.—In order to determine the length of time the gelatinous egg masses can be removed from the water and exposed to the relatively dry air and remain viable, the following experiment was performed in the laboratory with *C. lobiferus* and *C. cingulatus* egg masses from the lakes.

The first possible field condition it was desired to duplicate was one in which the water level of the lakes receded sufficiently to expose egg masses to the air but left them lying on a moist surface. A series of egg masses were therefore placed upon moist blotting paper in open petri dishes and exposed to the air for varying periods before being covered with water. The longest exposure was of 72 hours; the blotting paper was kept moist throughout the period. In all cases there was complete hatching of the eggs after they were covered with water.

To duplicate a condition where the surface upon which the eggs were lying became dry, egg masses were placed in dry petri dishes and exposed for varying periods before being covered with water. Table 4 gives the results.

**Table 4.—Effect of drying upon hatching of eggs.**

| | Degree of Hatching | | | |
|---|---|---|---|---|
| Length of Exposure | After 42 hrs. | After 68 hrs. | After 92 hrs. | After 140 hrs. |
| 4 hours | Complete | | | |
| 5 hours | 9/10 Hatched | Almost Complete | Almost Complete | Complete |
| 6 hours | 3/4 Hatched | 9/10 Hatched | Almost Complete | Complete |
| 7 hours | None | None | None | None |
| 8 hours | None | None | None | None |

LARVAE.—The larvae of all the several species dealt with in this paper are apneustic; they do not have to come to the surface to breathe but obtain their oxygen from the water.

*Chironomus:* The larvae of all the species of *Chironomus* breeding in the lakes construct tubes or burrows within which they generally spend almost all of their larval life. In the laboratory, fourth instar *C. tenuicaudatus* larvae constructed cases and established themselves therein within 1¼ hours after introduction into a new culture; *C. cingulatus* and *C. lobiferus* constructed cases overnight.

These larvae most generally obtain their food by means of an induced flow of water through their tubes. This current of water, caused by the rhythmic undulatory movements of the larvae within their tubes, is probably of primary importance in supplying the oxygen requirements of the larvae but it also carries into the tubes the particles of possible food materials suspended in the adjacent water.

In addition, the larvae have often been observed feeding on inorganic matter outside the tube within a radius of about three-quarters of the larval body length.

The larva emerges rather cautiously from its tube and searches about for food material. The caudal end of the body is kept well anchored within the tube. Any food encountered is eaten; if fairly sizeable the larvae may attempt to drag it closer to the tube. While extended from its tube in this manner, the larva is extremely wary and a sudden movement nearby or any other change in the immediate environment will cause it to withdraw very rapidly into the tube.

This type of feeding is not continuous but is periodically interrupted. The larva draws itself back into the tube, either completely or with just the head protruding outside, and begins its rhythmic undulation which continues for a more or less short period of time. The larva may then again emerge from the tube and feed.

These breathing and feeding habits of the larvae are important from the standpoint of control since they serve to bring suspended particles of undissolved contact or stomach poisons which have been applied to the water into the tubes of the larvae.

In order to secure information concerning the ability of the larvae to develop under conditions of low food availability, two cultures were set up in shallow traps and newly hatched larvae of *C. lobiferus* introduced into each on August 16. The first tray contained only washed sand and tapwater. The larvae were given only occasional nourishment in the form of a drop of skim milk. On November 14 those larvae still alive were light yellow in color and quite transparent. At this time the introduction of a drop of skim milk daily was begun. By November 30 the larvae were pink in color, on December 13 they had turned blood red and on January 17 four pupae were found; these died shortly thereafter.

In the second tray organic debris from the lake bottom was added to the sand and tapwater; skim milk was added in the same quantities and at the same intervals of time as in the culture previously described. By September 26, the larvae were blood red in color and on October 18, the first adults emerged. These results would indicate that, other conditions being favorable, chironomid larvae can manage to exist for relatively long periods of time with a minimum of available food and that the availability of food can strongly affect the duration of the larval stage.

Some comment should also be made concerning the ability of the larvae to survive under adverse moisture conditions. It had been noted in the field that live larvae could be found in moist portions of the shore from which the water had receded due to a drop in the lake level. In some cases live larvae were found in only slightly moist sand which, it was known, had not been covered with water for at least ten days. To check these observations, some marsh sod containing *lobiferus* larvae was removed from the lake bottom and brought into the laboratory where the free water was filtered off and the material spread to dry. Three days later, the sod had dried out very considerably. In one section, which was only somewhat damp, two live larvae were discovered partially exposed to the air. When placed in water, they showed no ill effects as a result of their prolonged exposure. The next day, two additional larvae, which had not been visible before, were found in the practically dry sod. When placed in water they displayed characteristic activity.

It would appear, then, that *Chironomus* larvae can exist for considerable periods of time in a moist environment not covered with water.

*Procladius and Tanypus:* The larvae of *P. culiciformis*, *P. choreus* and *T. punctipennis* do not construct tubes but live free in the muck at the bottom of the water.

Although these larvae are reported in the literature as predacious, the author has never observed this phenomenon in the case of the *Procladius* larvae. *Tanypus* larvae were often seen inside *Chironomus* egg masses feeding upon the newly hatched larvae; in one case a *Tanypus* larva was observed to kill and partially devour the contents of a *C. lobiferus* larva. That *P. culiciformis* and *P. choreus* larvae are not predacious would seem to be indicated by the fact that these organisms were present in the lake bottom in large numbers during the summer of 1939 at a time when there were extremely few *Chironomus* or other insect larvae present to serve as food. During the same period, *T. punctipennis* larvae were also extremely rare.

The hypothesis might be advanced, then, that *T. punctipennis* is completely dependent upon its predacious habits for food while *P. culiciformis* and *P. choreus* are able to thrive upon non-living food.

PUPAE.—The pupae of *C. lobiferus*, *C. cingulatus* and *C. brachialis* are relatively inactive. Pupation occurs within the larval tube and the pupae generally remain in or near the tube on the lake bottom until shortly before adult emergence. The pupae then become somewhat more active and finally come to the surface of the water where the adult emerges.

The pupae of *C. tenuicaudatus*, *T. punctipennis*, *P. culiciformis* and *P. choreus* are much more active; those of the last three species move about in the water throughout the pupal stage, while the pupae of *C. tenuicaudatus* are very active during the greater portion of the period.

The emergence of the adults from the pupal skins occurs very rapidly; the entire process takes no more than a few seconds. The pupa rises to the surface, the pupal skin splits along the dorsum of the thorax, and the adult climbs out, taking wing almost immediately.

ADULTS.—*Chironomus tenuicaudatus* which emerged in the laboratory lived, on the average, for two and one-half days. *C. cingulatus*, *C. lobiferus* and *C. brachialis* adults lived an average of five days under laboratory conditions; one *C. lobiferus* male lived for nine days which was the maximum adult life duration recorded. In general, males lived longer than females.

Females which had emerged in the laboratory deposited eggs even though they had not mated; such eggs were sterile. Females captured near the lakes oviposited readily in the laboratory. No mating was observed to occur within the small (18 by 18 by 22 inch) laboratory breeding cages, although cages were repeatedly stocked with newly emerged males and females.

*Procladius* adults copulate in the air and paired couples can be seen leaving the swarm of males. The female oviposits while resting on the surface of the water. The egg mass begins sinking to the bottom immediately.

A description of oviposition by a *C. tenuicaudatus* female follows: The female was noticed restlessly shifting from the surface of the water to the vertical surface, about one inch above the water, of a raft. This was repeated several times. During each resting period, it was observed that the female was supporting herself on the two anterior pairs of legs while the posterior pair were extended backward, parallel to and below the midline of the abdomen. The wings were kept in constant fluttering motion. During one rather longer period while the female was resting, head upward, on the vertical surface of the raft, the completely extruded egg mass was observed resting on the posterior tibiae. The female took off once more and the egg mass dropped to the surface of the water, apparently as a result of a sudden sharp movement of the posterior pair of legs.

DURATION OF LIFE CYCLES.—Based upon field and laboratory observations, the duration of the life cycle, adult to adult, of *C. lobiferus* and *C. cingulatus* is about 30 days in midsummer. That of *C. tenuicaudatus* is probably the same or slightly shorter. Not all individuals from a single egg mass mature with equal rapidity, however. A spread of more than three weeks between the emergence of the first and last adults from a culture started with a single egg mass has been noted.

The life cycle of the *Procladius* spp. is about 28 days in early spring and three weeks in midsummer.

CONTROL.—Very little work has apparently been done on the control of the Chironomidae. Much of the literature concerning these insects deals purely with the biology of a number of species. Interest seems to have been directed at their propagation as a source of fish food rather than at their control. However Buchmann (1932) has investigated the control of bloodworms breeding in swimming pools and in activated sludge plants for the treatment of sewage. During the progress of the control operations there came to hand a report of the Department of Public Health and the Department of Public Works of Massachusetts (1938) concerning the control of midge breeding in a salt water pond. Herms (1937) investigated the control of a non-biting fly (*Chaoborus*) of fairly similar habits which was troublesome only because of its very great numbers.

LABORATORY TOXICITY TESTS.—Shortly after beginning these investigations large numbers of chironomid larvae were taken from the lake bottom and established in shallow trays in the laboratory to serve as a source of supply for biological and toxicity studies. This was continued during the winter months. Overwintering larvae were taken from the lakes to replenish the supply in the laboratory whenever needed.

A considerable number of possible toxic materials were tried. The results of the tests with the more promising of these materials follow below. Although *C. lobiferus* is mentioned as the experimental species in most cases, it should be mentioned that small numbers of *C. cingulatus* larvae were also used.

*Paris Green and White Arsenic:* These materials were tested against *lobiferus* and *brachialis* larvae established in shallow trays. The powder in each case was first wetted with water and then sprayed over the surface of the water in the trays. All tests ran for three days.

Paris Green applied on the basis of 5 lbs. per acre effected an average mortality of 81 per cent. At the rate of 10 lbs. per acre the mortality was 87 per cent. The average mortality in the controls was 36 per cent.

The White Arsenic powder ($As_2O_3$) used had previously been made wettable. At 10 lbs. per acre the mortality was 78 per cent and at 20 lbs. per acre it was 87 per cent; the controls averaged 34 per cent.

*Sodium Chloride: C. lobiferus* larvae were introduced into battery jars and sodium chloride was dissolved in the water therein in varying amounts with the results shown in table 5.

Although Buchmann (1932) reported considerable success with pyrethrum in controlling chironomid breeding in an activated sludge plant, and stated that a dose of 3 mg. per liter of sewage would cause a mortality of at least 80 per cent, this material was not investigated further since the more favorable price and toxicity results with derris powder made that seem more promising.

After actual control operations had been begun in the spring of 1939, using derris powder as the toxic agent, it was found that the degree of control of *Procladius* larvae was not nearly as good as that of *Chironomus* larvae. A laboratory toxicity test against *Procladius* larvae with a concentration of 12 p.p.m. of derris powder resulted in a mortality of only 28 per cent. An emulsion of orthodichlorbenzene, 80 per cent, and sulfonated castor oil, 20 per cent, gave much better results in the laboratory, a concentration of 9.6 p.p.m. (by volume) of the emulsion resulting in 100 per cent mortality after 72 hours. This material has not yet been tested under field conditions.

**Table 5.—Effect of sodium chloride on larvae of midges.**

| PER CENT NaCl | PER CENT MORTALITY AFTER | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 2 hrs. | 4 hrs. | 21 hrs. | 28 hrs. | 46 hrs. | 52 hrs. | 93 hrs. | 100 hrs. |
| 0.5 | 0 | 0 | 5 | 5 | 5 | 5 | 10 | 15 |
| 0.75 | 0 | 0 | 0 | 0 | 0 | 5 | 15 | 20 |
| 1.00 | 0 | 0 | 10 | 10 | 15 | 20 | 80 | 95 |
| 1.25 | 0 | 0 | 10 | 60 | 100 | | | |
| 1.50 | 0 | 0 | 65 | 100 | | | | |
| 1.75 | 15 | 20 | 100 | | | | | |
| 2.00 | 15 | 75 | 100 | | | | | |
| 3.00 | 60 | 90 | 100 | | | | | |
| Control | 0 | 0 | 5 | 15 | 15 | 15 | 30 | 40 |

CONTROL OPERATIONS.—*Control Apparatus:* Since the time available between the inception of these investigations and the control "deadline" was very definitely limited, immediate attention had to be given to the type of apparatus to be used for the actual field control operations. The drawing up of specifications for the field equipment was begun before the toxic agent was definitely decided upon and the apparatus therefore had to be of a type that could be used efficiently with most, if not all, of the toxic materials under consideration.

The spraying outfit finally evolved con-

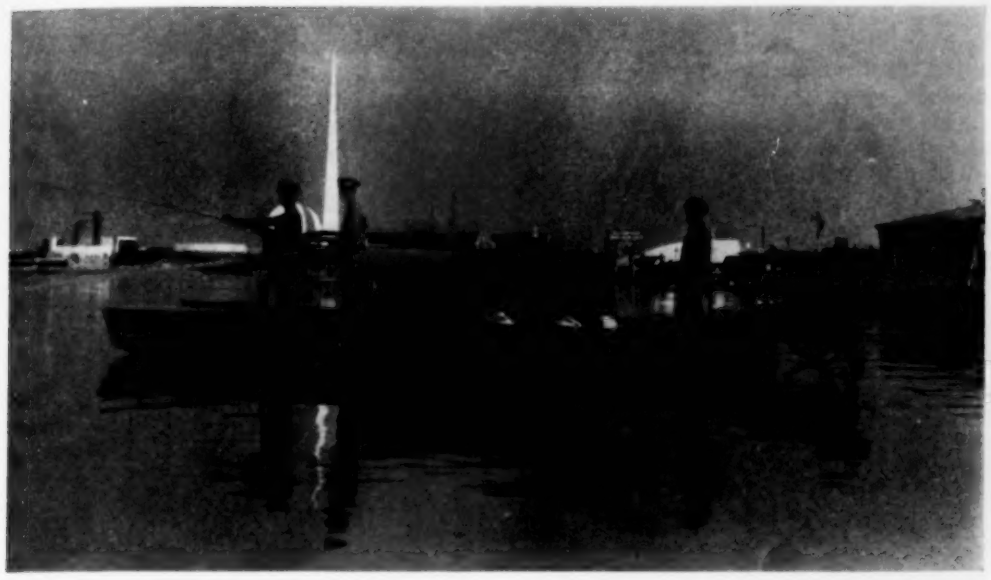

FIG. 2.—Sprayer used in midge control operations.

sisted of a sturdily constructed shallow-draft, flat-bottom barge, 12 ft. by 22 ft., on which was mounted a high-pressure sprayer. The barge was propelled by a 16.2 H.P. outboard motor equipped with an oversize propeller. The sprayer consisted of a 300 gallon divided wooden tank with two agitator propellers in each section, a 30 gallon per minute, 800 pound pressure pump and a 25 H.P. gasoline engine mounted with the pump.

The suction line from the pump of the sprayer was divided; one division was equipped with 10 feet of 2 inch suction line, with a strainer, and the other division extended to the tank. Between the tank and the suction hose connection, there was installed a meter and gauge capable of passing 1½ to 12 gallons per minute, which showed accurately the rate of withdrawal from the tank. The flow through the meter was controlled by a gate valve.

When operating, the strainer end of the hose suction line was kept over the side of the barge in the lake water. By opening or closing the gate valve the amount of liquid pulled from the tank through the meter could be accurately regulated. Since the suction of the pump was constant, the balance of the pump capacity consisted of water drawn from the lake. In this way the tank could be

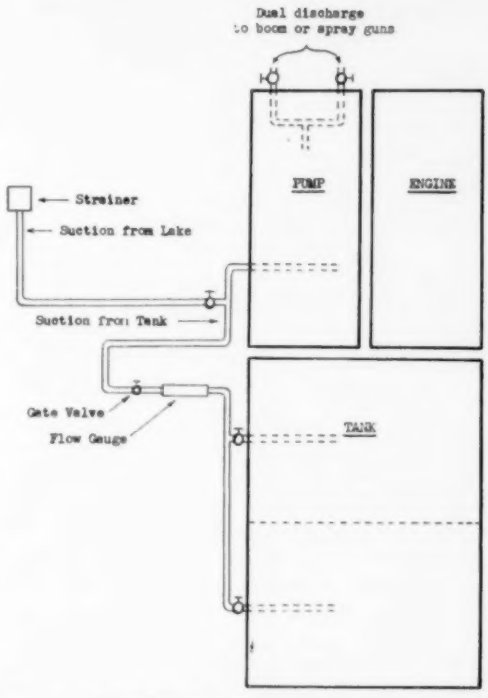


FIG. 3.—Diagrammatic representation of divided suction line and flow meter arrangement on sprayers used in midge control operations.

filled with a concentrated solution or emulsion and, by regulating the flow through the meter, any given proportion of concentrate to lake water could be

secured at the spray nozzles within the limits 1:14 and 2:3. The assembly of this outfit, in a general manner, is shown in figure 3.

Off the stern of the barge there was mounted a pipe spray boom similar to those used for truck crops. This was 20 feet long (1 ten and 2 five foot sections) and bore 21 equally spaced spray nozzles equipped with fan-spray disks. Each section of the boom had its own feed hose from one lake to the other because of a low bridge, one was permanently stationed in the smaller lake while the other two were kept in the larger lake. In this way each barge covered about 50 acres.

MATERIALS USED AND PROCEDURE FOLLOWED.—Although a number of toxic materials had given promising results in the laboratory toxicity tests, derris powder was decided upon as the poison to be employed.

**Table 6.—Control of aquatic midges by various treatments. Laboratory tests in battery jars.**

| MATERIAL | CONCENTRATION | PER CENT MORTALITY AFTER PERIODS INDICATED (HOURS) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 2 | 18 | 20 | 25 | 42 | 46–52 | 67–68 | 70–73 | 90–93 |
| o-dichlorobenzene | (vol.) | | | | | | | | | |
| | 3 p.p.m. | 52 | | 76 | | | | 92 | | |
| | 6 | 64 | | 92 | | | | 100 | | |
| | 12 | 92 | | 100 | | | | | | |
| Control | | 0 | | 4 | | | | 24 | | |
| Trichlorbenzene | 3 | 40 | 60 | | | 60 | | 70 | | |
| | 6 | 40 | 60 | | | 100 | | | | |
| | 12 | 70 | 90 | | | 90 | | 100 | | |
| Control | | 0 | 10 | | | 30 | | 30 | | |
| Cresylic Acid* | 6 p.p.m. | 0 | 0 | | | | 15 | | | 80 |
| | 12 | 5 | 15 | | | | 80 | | | 95 |
| | 24 | 75 | 100 | | | | | | | |
| Control | | 0 | 5 | | | | 5 | | | 5 |
| | (Weight) | | | | | | | | | |
| Copper sulphate | 30 p.p.m. | | | | | | | | 75 | |
| | (vol.) | | | | | | | | | |
| Chloropicrin† | 4 p.p.m. | | | | 76 | | | | | |
| | 8 | | | | 100 | | | | | |
| Pyrethrum powder | (Weight) | | | | | | | | | |
| (0.9% pyrethrins) | 3 p.p.m. | | 0 | | 5 | | | 10 | 15 | 15 |
| | 6 | | 10 | | 15 | | | 35 | 60 | 80 |
| | 12 | | 25 | | 25 | | | 70 | 85 | 100 |
| Control | | | 5 | | 10 | | | 35 | 35 | 35 |
| Derris, 5% | 3 p.p.m. | | 10 | | 20 | | | 30 | 45 | 65 |
| Rotenone | 6 | | 5 | | 60 | | | 100 | | |
| | 12 | | 25 | | 75 | | | 100 | | |
| | 2 | | | | | | 55 | | | |
| | 3 | | | | | | 50 | | | |
| | 4 | | | | | | 90 | | | |
| | 5 | | | | | | 95 | | | |
| | 6 | | | | | | 100 | | | |
| Control | | | | | | | 10 | | | |

* Refined; paramethyl phenol, reported to contain 75% alkyl phenols.
† Emulsion; 50% chloropicrin and 50% liquid soap.

and the flow through each could be controlled by means of a quick-action snap valve. The boom was set at such height that the fans of spray from the nozzles just overlapped as they reached the water.

The barge was also equipped with two shade trees guns together with appropriate lengths of hose. The spraying could therefore be performed through the boom or by means of the spray guns.

Three such spray outfits were constructed. Since the barges could not pass

In conjunction with each derris application, copper sulphate was dissolved in the lakes at the rate of 1 p.p.m. in order to kill most of the algae therein which served as a source of food and shelter for the larvae, particularly those of the *C. tenuicaudatus* group, and also to increase the potency of the derris by reducing the alkalinity of the lake water.

Spraying was started in April 10th when the water temperature reached 50 degrees and the overwintering larvae

started to show signs of activity. Sufficient derris of 5 per cent rotenone content was applied to build up a concentration of 6 p.p.m. (a dilution of 0.00003 per cent rotenone) in Willow Lake and a concentration of 10 p.p.m. (a dilution of 0.00005 per cent rotenone) in Fountain Lake. The results were very striking, particularly in Fountain Lake. Many dead or dying bloodworms were soon observed floating on the water, thousands of others were washed ashore and the lake bottom was covered with the dead and decomposing bodies of the larvae. Thereafter the intervals between treatments was based upon the life-cycle of the species involved.

The procedure used in making the derris application was as follows: Before starting from its dock in the morning each barge was loaded with twelve 50 pound bags of derris and five 100 pound bags of copper sulphate. When the barge reached the starting point in its assigned area, the tank was filled to about one-third of its capacity with lake water. One bag of derris powder was then dumped into the tank, 25 pounds to each section, and the tank filled to the top with water. The heavy load of powder was kept in even suspension by the four agitator propellers. One bag of copper sulphate was lowered into the water, attached to the stern of the barge. The spraying was then begun. The barge worked across the lake starting at one end of its territory and spraying adjacent lanes until the territory had been covered. The barge then sprayed the shore line of its area and then started the general spraying of its area again. Thus each barge covered its territory at least seven times for each treatment.

During the day, additional derris, copper sulphate and gasoline was brought out to each barge as necessary. There was a three man crew on each barge and it was found that this crew could apply 1200 to 1500 pounds of derris per day.

RESULTS.—The control operations were extremely effective against *C. lobiferus*, *C. cingulatus* and the *C. tenuicaudatus* group of small green midges. These had been the dominant species present during the summer and fall of 1938. The other *Chironomus* species and the *Tanytarsus* were also very definitely under control.

The degree of control of *Procladius*, however, was not nearly as good. As indicated previously, laboratory tests made after control operations were in full swing indicated that derris, for some reason, was not as toxic to *Procladius* as to *Chironomus* larvae. However, the number of *Procladius* adults that emerged was kept down very considerably by measures directed against the pupae. The active pupae tended to congregate in great numbers in protected places on the lee shore of the lakes and could be killed there by spraying with derris or with the pyrethrum-kerosene emulsion that was used for the control of mosquito breeding.

For some reason, not definitely known, *T. punctipennis* which had been as abundant, as the *Procladius* species during 1938, did not appear in 1939.

The catches made by two mosquito light-traps in operation near the lakes serve to indicate the degree of control achieved by the operations described. During the summer of 1938, the jar at the bottom and much of the large funnel inside each trap would be jammed full of midges after operating one night while in 1939, only a thin layer of midges would be found in the jars.—11-16-39.

Acknowledgement.—The author is greatly indebted to Doctor John L. Rice, Commissioner, and Dr. John G. Grimley, Special Deputy Commissioner of the New York City Department of Health and to the New York World's Fair Corporation, particularly Mr. Grover Whalen, President, and Commander Howard A. Flanigan, Executive Vice President, for much counsel, assistance and encouragement in the prosecution of the work. The investigations and control operations were conducted under the general supervision of Commissioner Rice and under the personal direction of Doctor Grimley.

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# Rotenone-Bearing Insecticides for the Control of the Elm Leaf Beetle, *Galerucella xanthomelaena* Shrank[1]

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Rotenone-bearing insecticides have been tested for the past two seasons in comparison with arsenate of lead for the control of the elm leaf beetle, *Galerucella xanthomelaena* Schrank. The present report is preliminary in nature and further tests under varied weather conditions with different dilutions and times of application are necessary to establish finally the value of these materials for the control of this pest. However, the results obtained thus far appear to be of sufficient promise to warrant presentation at this time.

The elm leaf beetle has been quite abundant in many areas of western New York for several years. As a result many valuable trees have been either killed outright or seriously weakened through repeated attacks. Trees in poor vigor are of particular importance in, and adjacent, to those areas where the Dutch elm disease is present or where vector-species of the elm bark beetle are known to occur. In following this problem it has been apparent that there is a definite demand on the part of many individuals charged with the responsibility for elm leaf beetle control for a relatively non-poisonous spray mixture leaving no visible residue which can be used under a wide variety of urban conditions and thus obviate complaints from home owners. The main objections offered to arsenate of lead are the fear of poisoning children and domestic animals and the whitish residue on sidewalks, grass, cars, buildings or other objects. Hence our interest in the rotenone-bearing spray mixtures.

During the past decade the effectiveness of rotenone-bearing insecticides has been demonstrated with a number of insect pests. Hamilton (1937), reports "The derris powder or cubé powder, rosin residue emulsion was effective as a contact spray against the larvae of the elm leaf beetle, willow leaf beetle, and Mexican bean beetle and had some repellent action against the adults." Of the five tests conducted, two were reported as giving satisfactory control and three were reported as unsatisfactory. Brief statements regarding the results given in the present paper have already been published (Parrott, 1938 and 1939).

SEASONAL HISTORY.—The emergence of overwintering adults naturally varies somewhat with seasonal conditions and is closely related to the seasonal development of plant growth. For instance, the first appearance of adults from hibernation and evidence of feeding injury were observed on May 6 in 1938 as compared with May 12 in 1939. Likewise, the first evidence of egg-laying was on May 19 in 1938 and May 26 in 1939. Beetles and unhatched eggs may be found on

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the foliage as late as the first week of July. During most years the eggs begin to hatch about the end of the first week in June and continue over a period of several weeks. The earliest record of hatching in both 1938 and 1939 was June 5. Pupation was first observed on July 6 in 1938 and July 5 in 1939. In 1939 emergence of first brood adults was observed July 19. Regarding the variation in dates of appearance of beetles, egg-laying, hatching and pupation in western New York during 1938 and 1939, it should be pointed out that plant activity started rather early in 1938 and was accompanied by unsually warm weather for a short period but was followed by a decided drop in temperature, whereas in 1939 plant development proceeded somewhat more slowly in the early part of the spring but unusually hot, dry weather and rapid growth followed. Thus, during these two years, there was a noticeable equalizing effect of some stages of development of the insects by early June; however, on June 16, 1938, and June 14, 1939, it was found that 79 and 58 per cent, respectively, of the egg masses present on the leaves had hatched.

Since it is difficult to forecast definitely the dates of appearance of certain stages of the insect or dates for applying control measures, certain phenological information appears to be of value for this purpose. These data are as follows: May 19, 1938 and May 26, 1939—*Spiraea Vanhouttei* Zabel just beginning to bloom; common lilac *Syringa vulgaris* L. past full bloom; Persian lilac *S. persica* L. in full bloom; *Syringa villosa*, Vahl. not yet open; black locust *Robinia pseudacacia* L. and red clover *Trifolium pratense* L. in bloom; petals beginning to fall on Rhode Island Greening apples. This stage of plant growth conforms with that of the beginning of egg-laying by the overwintering elm leaf beetle. On June 11, 1938 and June 14, 1939, 70 to 80 per cent and 50 to 58 per cent of the egg masses present had already hatched. Mock orange, *Philadelphus* sp. and German iris, *Iris germanica* L. were past full bloom; climbing and hybrid tea roses and *Catalpa speciosa* Warder, and *Deutzia gracilis* S. & Z. were in bloom; Dorsett strawberries were ripening; and Montmorency cherries were showing red color. Observations of this nature during 1938 and 1939 indicate that the proper time for application of the larval spray conforms quite closely with stages of plant growth indicated above.

**Table 1.—Elm Leaf Beetle Control, Midvale, N. Y. 1938.**

| Treatment Applied | | Counts Made | Larvae | | |
|---|---|---|---|---|---|
| Material | Date | | Number Dead | Number Alive | Per cent Dead |
| | June | June | | | |
| Cubé powder (4% rotenone), 4 lbs., | 16 | 18 | 325 | 10 | 97.0 |
| *IN-181*, 4 ozs., water, 100 gals. | 16 | 20 | 538 | 8 | 98.5 |
| Arsenate of lead, 6 lbs., | 16 | 18 | 142 | 0 | 100.0 |
| *Orthol-K ready mix oil*, 1 gal., water, 100 gals. | 16 | 20 | 215 | 0 | 100.0 |
| Check (untreated) | | 18 | 0 | 70 | 0.0 |
| Check (untreated) | | 20 | 0 | 345 | 0.0 |

Experimental Procedure.—All tests were conducted with heavily infested elms in cities and villages. In the experiments reported in tables 2 and 3, sprays were applied with a 35-gallon per minute sprayer at 600 pounds pressure, using either a standard orchard spray-gun or a park-gun, as conditions necessitated. The sprays at Penn Yan, reported in table 4, were applied with a 25-gallon per minute sprayer at 600 pounds pressure using a park spray-gun. Since observations made shortly after the cubé spray was applied, on June 16, 1938, indicated that this material was killing either the unhatched eggs or the larvae before emerging from the egg-shell, it was decided to keep records on both egg masses and larvae. As will be seen in tables 2, 3, and 4 data

were taken on the numbers of larvae and hatched and unhatched eggs for each treatment and for unsprayed trees. Leaves and branches showing evidence of larval feeding or of egg masses were selected at random on all sides of the tree. In some instances, as for example in table 4 in the arsenate of lead and stabilized derris treatments, it was difficult to find more than a few larvae even though many leaves or branches which bore egg masses were examined. When considered in terms of the total number of eggs present as compared with the number that actually hatched, the percentage of larvae recovered at the time of counting was invariably higher on trees sprayed with derris than on those sprayed with arsenate of lead. This fact was noticeable even when counts were made only a few days after treatment, but was more pronounced when counts were delayed from one to two weeks after application. Apparently derris acts to a considerable extent as a contact poison whereas arsenate of lead is a stomach poison. Consequently, larvae which ingest arsenate of lead gradually become weaker and many of them are apparently unable to remain attached to the leaf surface. On the contrary, larvae that are covered with the derris spray are killed much more quickly; in fact many larvae were found dead at the point where they were feeding when the spray was applied. These observations indicate that in obtaining data on experimental plats it may be necessary to make counts at different intervals after application where such materials as derris and arsenate of lead are used, even though all treatments are applied on the same date.

**Table 2.—Elm Leaf Beetle Control, Midvale, N. Y. 1939.**

| Treatment Applied | | Counts Made | Larvae | | | Eggs | | |
|---|---|---|---|---|---|---|---|---|
| | | | Number Dead | Number Alive | Per Cent Dead | Hatched Number | Not Hatched | |
| Material | Date | | | | | | Number | Per Cent |
| Regular ground derris | June | June | | | | | | |
| (5% rotenone),* 4 lbs., | 6 | 16 | 125 | 146 | 46.1 | — | — | — |
| soybean oil,† 1 pt., | 6 | 28 | 18 | 22 | 45.0 | 343 | 38 | 10.0 |
| *Binderine* (*Goulac*), 1 lb., | 6 & 14 | 16 | 106 | 0 | 100.0 | — | — | — |
| water, 100 gals. | 14 | 16 | 145 | 0 | 100.0 | — | — | — |
| | 14 | 28 | 283 | 0 | 100.0 | 1055 | 126 | 10.7 |
| | 20 | 28 | 462 | 0 | 100.0 | 1277 | 772 | 37.7 |
| *Stabilized* ground derris | 6 | 16 | 34 | 3 | 91.9 | — | — | — |
| (4.85% rotenone*), 4 lbs., | 6 | 28 | 28 | 6 | 82.3 | 362 | 686 | 65.5 |
| soybean oil,† 1 pt., | 6 & 14 | 16 | 137 | 6 | 95.8 | — | — | — |
| *Binderine* (*Goulac*), 1 lb., | 14 | 16 | 145 | 0 | 100.0 | — | — | — |
| water, 100 gals. | 14 | 28 | 179 | 53 | 77.2 | 954 | 212 | 18.2 |
| | 20 | 28 | 220 | 0 | 100.0 | 700 | 16 | 2.2 |
| Arsenate of lead, 6 lbs., | 6 | 16 | 29 | 48 | 37.7 | — | — | — |
| hydrated lime, 3 lbs., | 6 | 28 | 57 | 32 | 64.0 | 918 | 80 | 7.0 |
| soybean oil,† 1 pt., | 6 & 14 | 16 | 22 | 54 | 29.0 | — | — | — |
| soybean flour,† 1 lb., | 14 | 16 | 72 | 20 | 78.3 | — | — | — |
| water, 100 gals. | 14 | 28 | 157 | 1 | 99.4 | 1526 | 125 | 7.6 |
| | 20 | 28 | 138 | 67 | 67.3 | 886 | 79 | 10.2 |
| Check | | 16 | 0 | 225 | 0.0 | — | — | — |
| | | 28 | 5 | 218 | 2.2 | 363 | 18 | 4.7 |

* Both regular and "stabilized" derris were supplied by the United States Rubber Company.
† Both soybean flour and soybean oil were supplied by The Glidden Company, Soya Products Division, Chicago, Illinois.

EXPERIMENTS IN 1938.—American, Chinese and Wych elm (*Ulmus americana* L., *U. pumila* L., and *U. glabra* Huds.) were sprayed with cubé powder and with arsenate of lead at Midvale and Geneva. The dilution of the materials and the results are given in table 1. It should be pointed out that what appeared to be a pronounced foliage injury developed, on American elm trees sprayed with the arsenate of lead-oil mixture, in the form of marginal browning and yellowing and browning of other portions of the leaves. It is quite possible that this condition was accentuated by leaf-spot infection.

EXPERIMENTS IN 1939.—In view of the promising results obtained in 1938 more extensive experiments were planned in 1939. The experiment at Midvale, was designed to determine the proper time and number of applications necessary to control the larvae. Both American and Wych elms were treated. In this test three applications were made, on June 6, 14, and 20. In this experiment there were trees which received a single application on (June 6, or 14, or 20); trees which received three applications (June 6, 14, and 20); trees which received two applications (June 6 and 14); and trees which received two applications (June 14 and 20). Thus it was possible to determine the effectiveness of single applications as well as of repeated applications made at different dates. The results of this experiment are given in table 2.

The purpose of the experiment located at Geneva (shown in table 3), was to determine the efficiency of reduced dosages of derris and of arsenate of lead applied at the time of maximum hatching. In the tests at Penn Yan, both the labor for spraying and the spray machinery were made available through the cooperation of the village officials and all trees showing infestation were sprayed as a community project. Some 4,400 gallons of material were applied, and regular derris, stabilized derris and arsenate of lead all were used. Such an experiment surved to demonstate the effectiveness of these materials when applied under practical conditions with local officials in charge of spray operations. Details of the experiment are given in table 4.

SUMMARY.—The elm leaf beetle has been a serious problem in many towns and communities of western New York for several years. Insect activity and development, particularly as to emergence of beetles from hibernation, feeding, egg-laying and hatching, appear to be closely correlated with plant growth during different years. Egg-laying commences about the time that *Spiraea Vanhouttei* is beginning to bloom. Fifty per cent or more of the egg masses present had hatched by the time that *Catalpa speciosa*, *Deutzia gracilis* and hybrid tea roses were in bloom.

Experiments in 1938 indicated that sprays containing either 4 pounds of cubé powder or 6 pounds of arsenate of lead to 100 gallons of water were quite effective when applied after more than half of the eggs had hatched. In 1939 spray mixtures containing either derris (2 or 4 pounds) or arsenate of lead (4 or 6 pounds) in 100 gallons of water gave satisfactory control

**Table 3.—Elm Leaf Beetle Control, Geneva, N. Y. 1939.**

| TREATMENT APPLIED | | COUNTS MADE | LARVAE | | | EGGS | | |
|---|---|---|---|---|---|---|---|---|
| | | | Number Dead | Number Alive | Per Cent Dead | Hatched Number | Not Hatched | |
| Material | Date | | | | | | Number | Per Cent |
| Regular ground derris (5% rotenone),* 2 lbs., soybean flour,† 1 lb., water, 100 gals. | June 16 | June 19 | 259 | 0 | 100.0 | — | — | — |
| | 16 | 26 | 295 | 1 | 99.7 | 1354 | 330 | 19.6 |
| *Stabilized* ground derris (4.85% rotenone),* 2 lbs., soybean flour,† 1 lb., water, 100 gals. | 16 | 19 | 300 | 0 | 100.0 | — | — | — |
| | 16 | 26 | 368 | 0 | 100.0 | 896 | 162 | 15.3 |
| Arsenate of lead, 4 lbs., *Orthol-K* oil, 2 qts., hydrated lime, 4 lbs., water, 100 gals. | 16 | 19 | 61 | 43 | 58.6 | — | — | — |
| | 16 | 26 | 214 | 20 | 91.4 | 1150 | 173 | 13.1 |
| Check | | 19 | 0 | 168 | 100.0 | — | — | — |
| | | 26 | 3 | 138 | 2.1 | 213 | 0 | 0.0 |

* Both regular and "stabilized" derris were supplied by the United States Rubber Company, Development Department, Market and South Street, Passaic, New Jersey.
† Soybean flour was supplied by The Glidden Company, Soya Products Division, Chicago, Illinois.

if applied on or after the second week of June. Limited tests with 2.5 per cent rotenone extract, diluted 1 to 400, effected a high degree of control of both larbae and adults. Investigations to date do not necessarily indicate that rotenone sprays will entirely replace arsenate of lead in the spray program for the control of elm leaf beetle, but it seems probable in the column "per cent eggs hatched," show marked differences between regular and stabilized derris when applied on June 6 and June 9. However, further experiments are necessary to determine satisfactorily their effect on the unhatched eggs, larvae, and adults under a variety of weather conditions. The advantages of derris powder or rotenone extract sprays

**Table 4.—Elm Leaf Beetle Control, Penn Yan, N. Y. 1939.**

| Treatment Applied | | Counts Made | Larvae | | | Eggs | | |
|---|---|---|---|---|---|---|---|---|
| | | | Number | | Per Cent | Hatched | Not Hatched | |
| Material | Date | | Dead | Alive | Dead | Number | Number | Per Cent |
| Regular ground derris (5% rotenone), 4 lbs., *Grasselli Sticker-Spreader,** ½ pt., water, 100 gals. | June 9 | June 27 | 83 | 0 | 100.0 | 523 | 512 | 49.5 |
| Regular ground derris (5% rotenone), 2 lbs., *Grasselli Sticker-Spreader*, ½ pt., water, 100 gals. | 21 | 27 | 176 | 0 | 100.0 | 438 | 50 | 10.2 |
| Regular ground derris (5% rotenone), 2 lbs., soybean flour, 1 lb., water, 100 gals. | 22 | 27 | 176 | 0 | 100.0 | 283 | 13 | 4.4 |
| *Stabilized* ground derris (4.85% rotenone), 4 lbs., *Grasselli Sticker-Spreader*, ½ pt., water, 100 gals. | 9 | 27 | 4 | 0 | 100.0 | 68 | 194 | 74.0 |
| *Stabilized* ground derris (4.85% rotenone), 2 lbs., *Grasselli Sticker-Spreader*, ½ pt., water, 100 gals. | 21 | 27 | 105 | 8 | 92.9 | 232 | 70 | 23.2 |
| Arsenate of lead, 4 lbs. | 10 | 27 | 7 | 1 | 87.5 | 651 | 18 | 2.7 |
| soybean flour, 1 lb., | 23 | 27 | 81 | 48 | 62.8 | 334 | 10 | 2.9 |
| hydrated lime, 2 lbs., water, 100 gals. | | | | | | | | |
| Check | — | 27 | 3 | 107 | 2.7 | 241 | 9 | 3.6 |

* *Grasselli Sticker-Spreader* was supplied by E. I. du Pont de Nemours Company, Grasselli Chemical Department, Wilmington Delaware.

that under certain conditions these materials will be preferable. They should occupy an important field if present indications are borne out by further experiments, coupled with satisfactory reports from commercial tree-spraying companies villages or other organizations. In field tests no appreciable differences were noted between the effectiveness of regular derris and that of stabilized derris (containing an anti-oxidant), with the possible exception of the influence on the unhatched eggs. Data in table 2 and table 4, appear to include the lack of objectionable residue; relative safeness to man and pets; and rapidity of kill. The latter point is of particular importance when sprays are applied rather late in the season when many larvae are in the second or third instar and immediate relief from foliage injury is desired. The main disadvantages are the danger of poisoning fish, cost of the material, and possible lack of adhesion on foliage during heavy rains or wet weather. This latter objection may not prove to be serious inasmuch as the ma-

terial should be applied to the under surface of the leaf and also because of the fact that much of its effectiveness apparently results from the contact action of the spray within a short time after application.—11-16-39.

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# Parasitic Castration of *Anasa tristis* DeG. by *Trichopoda pennipes* Fab., and Its Effect on Reproduction,[1,2]

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Throughout the northeastern states the squash bug, *Anasa tristis* DeG., is commonly parasitized by a tachinid fly, *Trichopoda pennipes* F., the biology of which has been outlined by Worthley (1924).

The eggs of this fly are deposited on the surface of the host (fig. 1), and the maggot, upon hatching, bores through the integument to spend its three larval instars within the body cavity of the bug. Prior to its first molt, the maggot attaches itself to a tracheal trunk of the host in order that its own tracheal system, through its posterior spiracles, will have direct access to an adequate oxygen supply. The attachment is made, with few exceptions, to a trachea arising from the metathoracic spiracle on either the right or the left side of the bug. Until the larva emerges from its host to pupate, this attachment is maintained, the body of the maggot extending posteriorly into the abdominal cavity of the bug.

The only obvious injury to the host tissues caused by the developing maggot is to the reproductive organs. In these a progressive atrophy occurs, beginning when the maggot is in its second instar. At this time the injury is confined to the gonad on the side of the bug to which the maggot is attached. Promptly after the maggot reaches the third instar, the other gonad also gives evidence of degeneration. If a second stage larva is surgically removed[3] from its host, the one intact gonad retains its normal appearance and may continue to function normally while the affected organ fails to recover, thus indicating a permanent injury. This was shown in a number of cases in both sexes, the most striking case being a female. This individual deposited a total of 78

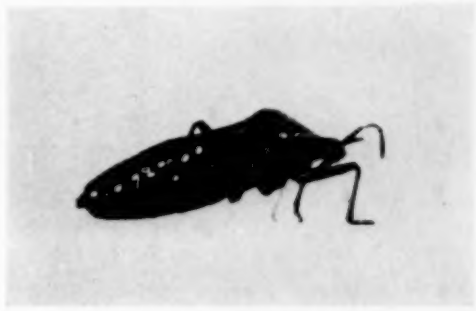

FIG. 1.—Side view of common squash bug bearing numerous parasite eggs. 2×. Regardless of the number of eggs present, only one parasite larva develops in a host.

eggs prior to the time of parasitization and another 50 before the maggot, in its second instar, was surgically removed. The bug lived 33 days after the operation during which time 76 eggs were deposited. Upon the death of this bug, the affected ovary was found to be entirely functionless, and undoubtedly the intact ovary

[1] This is a revision of part of a dissertation presented to the Faculty of the Graduate School of Yale University in candidacy for the degree of Doctor of Philosophy in 1939. The author wishes to express his gratitude to Dr. R. B. Friend for his suggestions in and criticism of this work.

[2] Awarded the Annual Medal of the Eastern Branch of the American Association of Economic Entomologists for the year 1939.

[3] The operation is made by anaesthetizing a bug, swabbing the surface with alcohol, and making an incision on the side of the first two visible abdominal segments. A longitudinal incision through these segments, joined by two lateral incisions, forms a flap hinged at the spiracular level. Through the opening made by raising the flap, a maggot can be removed. When replaced, the flap is quickly sealed by coagulation of the haemolymph.

had produced all the eggs which had been deposited during the interval between the operation and death.

The gross appearance of an affected ovary shows a marked shrunken condition (Fig. 2, B) as compared with the normal (Fig. 2, A). In advanced stages of degeneration, the egg tubes are collapsed and distorted, the oviducts are devoid of eggs, and only the germaria show any semblance of normal structure. Usually the first point of injury is just posterior to the second or third well-formed egg in the egg tube (Fig. 2, D). Posterior to this, more completely developed eggs may appear perfectly normal, and anterior to this, the germarium and oocytes in earlier stages of development show no abnormalities. As injury becomes more pronounced (Fig. 2, E), adjacent areas become atrophied. The eggs that may be present posterior to the original point of injury are deposited if sufficiently developed; they degenerate if not.

The injury is chiefly marked by a disappearance of yolk granules from the oocytes and a thickening and distortion of the ovariolar wall. Whether or not the disappearance of yolk is due to resorption is not at present understood. When degeneration is extreme, the ovarioles may become agglutinated by fatty tissue and by adhesion of the extensive tracheation. Even the germaria may become distorted, although the trophocytes and oocytes remain distinguishable.

A longitudinal section through a normal squash bug's testis (Fig. 2, F) shows the organ to be composed of seven lobes. Within each lobe the progressive stages of spermatogenesis are clearly demarcated, most of the structure being divided into spermatic cysts (Fig. 2, I). Testes

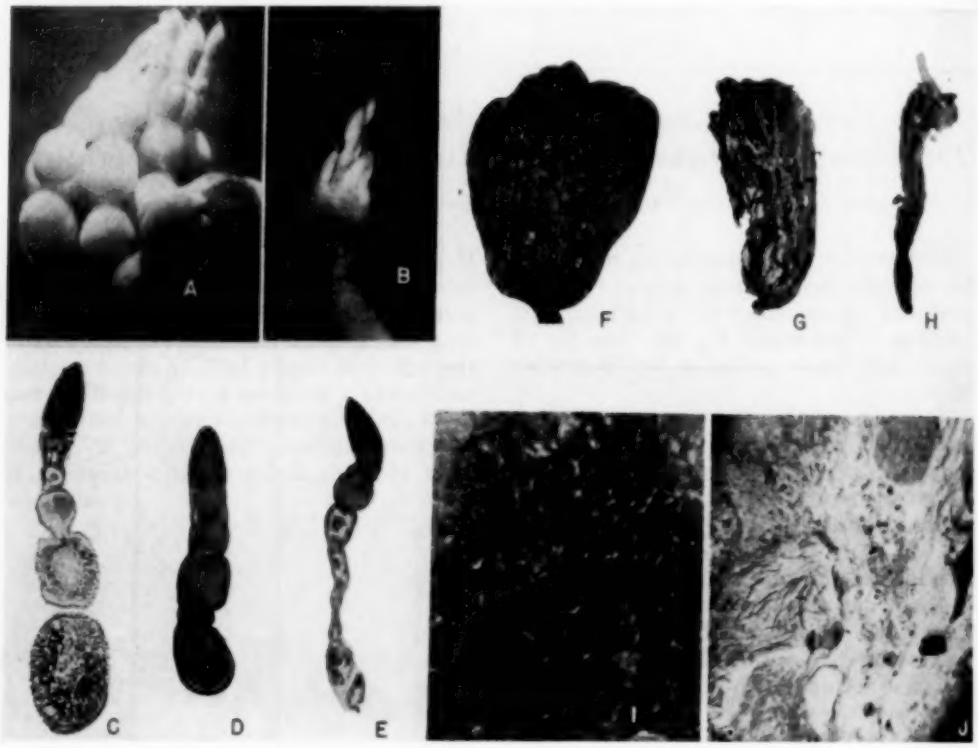


FIG. 2.—A, ovary from a normal squash bug; 7×. B, ovary from a parasitized squash bug; 7×. C, longitudinal section through a normal ovariole; 15×. D, longitudinal section through an ovariole showing initial injury; 12×. E, longitudinal section of ovariole showing advanced degeneration; 10×. F, longitudinal section of normal squash bug's testis; 24×. G, longitudinal section of partially atrophied testis; 23×. H, longitudinal section of completely atrophied testis; 20×. I, section of normal bug's testis, enlarged; 165×. J, section of atrophied testis, enlarged; 165×.

from a parasitized bug show less of a localized injury than do ovaries. The histological picture indicates that even at an early stage there is considerable destruction of tissue resulting in a general shrinking of the entire organ (Fig. 2, G). The most obvious effect is the complete destruction of many of the spermatic cysts. This destruction is progressive and ultimately no normal cysts are to be found (Fig. 2, H). An apparent abundance of connective tissue is presumably due to a loosening and spreading of the dense tissue forming the interlobular septa and the cyst walls (Fig. 2, J).

The nature of the mechanism by which this parasite larva causes the reproductive organs of its host to degenerate is not clear. Considering parasitic castration in a general way, Pantel (1910, 1913) distinguished between the direct effect on the gonad, in which a dipterous larva lives within the gonadal tissue, and the indirect effect, in which the larva resides outside of the gonad, exerting its influence through a systemic effect of a nutritional nature. In the case of the squash bug, the effect is clearly an indirect one, for the parasite does not live within the testis or the ovary. On the other hand, the indirect action is not in the nature of a systemic effect, nutritional or otherwise. This is most clearly shown by the fact that the two gonads within a parasitized bug do not degenerate simultaneously, in spite of the fact that they are symmetrically placed in the haemocoele. One may begin to atrophy several days before the other. Moreover, the effect is not reversible since once atrophy of the gonads sets in, recovery does not occur upon the removal of the causal agent. The nature of the localized action which must be responsible is not at present known, but histological preparations indicate that it is not due to purely mechanical injury. This is confirmed by failure to simulate the injury by surgically puncturing the gonad.

In the male squash bug, the degeneration of the testes causes no reduction in reproductive activity. In the first place, the spermatozoa stored in the seminal vesicles are adequate for the fertilization of eggs. This was shown by mating a parasitically castrated male with a virgin female. All eggs deposited by the female as a result of this mating were fertile. In the second place, since a single copulation is sufficient to fertilize the full complement of eggs in the female, and since mating begins in early spring, before castration sets in, no loss of fertility occurs.

In the case of the female, suppression of a certain amount of oviposition can be attributed to the parasite larva. Complete suppression was observed in one individual under experimental conditions. Early in June, 1938, before any oviposition had begun, a third instar maggot was surgically removed from a female squash bug. Although this bug lived 36 days following the operation, and mated frequently, no eggs whatever were deposited. Autopsy showed the ovaries to be in a state of complete atrophy. When the parasite exerts its effect after the commencement of oviposition, it is possible for many eggs to be deposited before parasitic castration is complete. In fact it is possible for eggs to be deposited by a parasitized bug up to within a few days prior to the emergence of the parasite and subsequent death of the host. The reason for this lies in the fact that the oviducts, pedicel, and even the distal regions of the ovarioles are not affected by the parasite. Normal eggs are frequently resident in these structures at the time the ovary itself becomes nonfunctional. Consequently the oviposition of parasitized female squash bugs continues until castration is complete and the oviducts are void of eggs. The time required by the parasite to accomplish this can be estimated from oviposition records of 68 parasitized bugs observed in 1937 and 1938. The last egg mass was found to have been deposited on the average of $13.07 \pm .07$ days after the parasite egg was affixed to the host.

It has been found that, in general, the mean daily oviposition of a squash bug during its reproductive season is 4.7 eggs.[4] It is thus possible to express the average number of eggs a parasitized bug will deposit by the formula: $y = 4.7\ x + 13.07$), in which $y$ = the total number of eggs deposited, and $x$ = the time of parasitization in days after the beginning of the oviposition period. This formula was applied to 87 parasitized bugs from which oviposition records had been obtained. The theoretical average obtained was $110.7 \pm 2.6$ eggs per female squash bug.

[4] Based on individual oviposition records of 101 female squash bugs during 1937 and 1938.

The average number actually obtained from these bugs was $105.7 \pm 5.5$ eggs. The small difference of 5 between these means is of no statistical significance, and the formula may be considered to yield a satisfactory estimate of the average number of eggs a parasitized bug probably deposits.

The extent to which oviposition in a natural population of squash bugs may be suppressed by *Trichopoda pennipes* is actually much less than might be supposed from an estimate of the apparent degree of parasitism—which at times is in excess of 85 per cent. By a careful consideration of factors too numerous to be discussed here, estimates of the suppression of oviposition attributable to this tachinid have been made for the past three years in a natural population of bugs at Mt. Carmel, Connecticut. For 1937 this amounted to a possible minimum of 28 per cent and a possible maximum of 42 per cent; for 1938 the estimated minimum was 3 per cent and the maximum 5 per cent; and in 1939 the suppression closely approximated 11 per cent.

SUMMARY.—Parasitic castration of the squash bug, *Anasa tristis* DeG., by the larva of the tachinid fly, *Trichopoda pennipes* F., is manifested by a progressive atrophy of the reproductive organs. This is due neither to a systemic effect nor to a strictly mechanical injury. The degeneration of the testes in the male squash bug causes no reduction in reproductive activity. In the female, the loss of functional ovaries is reflected in a limited suppression of oviposition, the extent of which has been estimated for a natural population during the past three years.—11-16-39.

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# Control of the Hawaiian Beet Webworm

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The Hawaiian beet webworm (*Hymenia fascialis* Cramer) was first reported as being a serious pest of early fall planted spinach in tidewater Virginia in 1926 by Poos (1926). Since that time this pest has occasionally injured fall spinach planted before September 10 in this area. In 1939, large numbers of Hawaiian beet webworm moths appeared about the middle of September and continued to be very abundant until about the first of November. The moths were numerous in fields of corn, soybeans, cabbage, kale, collards, beets, and spinach, in grassy areas, along ditch banks and wherever there was any vegetation that offered protection from the weather. However, beets and spinach were the only crops that were appreciably injured.

Poos (1926) reported that arsenical sprays and dusts did not control the pest. However, since then many reports have been received that growers were obtaining good control with calcium arsenate-hydrated lime dusts, a considerable quantity of which has been sold for this purpose. Several tests have been conducted with calcium arsenate-hydrated lime dusts and with rotenone bearing dusts at this station in the past five years for the control of the Hawaiian beet webworm. In these tests, even though the spinach leaves appeared to be well covered with the dusts, none of the materials gave satisfactory control. Occasionally the worms disappeared without seriously damaging the spinach, which probably accounts for many of the reports and opinions that the calcium arsenate dusts gave good control of this pest.

COMPARISON OF CALCIUM ARSENATE AND *PYROCIDE* DUSTS.—By the first of

October early planted spinach was becoming heavily infested with Hawaiian beet webworms and on October 5 an experiment was conducted to test the effectiveness of calcium arsenate, undiluted, and diluted with 50 and 75 per cent by weight of hydrated lime. A pyrethrum dust containing 10 per cent *Dry Pyrocide*[1] (0.2 per cent pyrethrins) was included in this test. The dusts were applied at the rate of 30 to 40 pounds per acre on a sunny day with a moderately strong breeze. Besides the 30 to 40 pound application of the 10 per cent *Pyrocide* dust, one bed about 200 feet long was very heavily dusted. In this test the feed outlet of the duster was adjusted to deliver its maximum dosage. The dusts were applied with a traction power duster which was equipped with eight nozzles arranged to cover a 75 inch bed of large spinach plants. The duster did not have a canopy or trailer. Within 30 minutes after the *Pyrocide* dust was applied the webworms began crawling wildly about on the plants and many of them, especially the larger ones, dropped to the ground and rolled over and over until they died.

Counts made 24 hours after treatment showed that the heavy application of *Pyrocide* dust had killed nearly 100 per cent of the webworms, that the lighter application had killed approximately 80 per cent, and that the calcium arsenate dusts had killed less than 15 per cent. The spinach dusted with the *Pyrocide* quickly outgrew the webworm injury, whereas the spinach dusted with the calcium arsenate dusts was so severely damaged that it was unfit for market.

Several spinach fields were dusted commercially with calcium arsenate dusts with negative results.

RELATIVE EFFECTIVENESS OF DIFFERENT AMOUNTS OF *PYROCIDE* DUST.—In view of the striking results obtained with the *Pyrocide* dust, an experiment was conducted on October 6, 1939, in which a 10 per cent *Pyrocide* dust was applied with a one-horse traction duster at the rates of approximately 35 and 60 pounds per acre. This duster proved to be too small to apply efficiently heavy dosages of as heavy a dust as *Pyrocide*, which probably accounts for the fact that the light application of dust gave as good results as the heavy application.

Fourteen hours after treatment there were 11 dead and 179 living worms on 30 untreated check plants, 144 dead and 22 living worms on 30 plants that had received the 60 pounds of dust per acre, and 114 dead and 17 living worms on 30 plants that had received the 35 pounds of dust per acre.

Counts were also made on the number of living webworms remaining on 30 plants taken at random from the treated and untreated beds 62 hours after treatment. At this time it was impossible to count the dead worms as many of them had been carried away by ants or otherwise disappeared. The untreated plants had an average of 30 webworms per plant as compared with an average of 3.4 and 2.0 webworms respectively for the plants receiving 35 and 60 pounds of dust per acre.

The treated plants were divided into two equal parts on October 17. One half of each treated plat was dusted again with 10 per cent *Pyrocide* at the rate of 35 pounds per acre to control small webworm larvae that were hatching at that time; the other half of each treated plat was left undusted. By the time these plats were harvested on November 22, the webworm population had greatly decreased, even on the check plats, and the spinach had made a partial recovery from the early injury.

YIELD AND QUALITY OF TREATED SPINACH.—Yield records were taken on six 150 foot sections of spinach beds from the untreated plats and from those receiving one and two dustings respectively. The untreated plats produced 775 pounds of poor quality spinach. The plats receiving one dusting produced 952 pounds of good quality spinach while those receiving two dustings produced 1040 pounds of slightly better quality spinach. When these data were analyzed statistically it was found that the yields produced by the plats receiving one and two dustings were not significantly different from each other, but that these yields were both significantly higher than the yields produced by the untreated check plats.

EFFECT OF MOISTURE ON EFFICIENCY OF DUST.—Following this test an experiment was conducted early on the morning

[1] *Dry Pyrocide* is a proprietary product made by extracting the active killing principles from pyrethrum flowers and impregnating an inert carrier with this extracted material.

**Table 1.—Experiments for the control of the Hawaiian beet webworm on spinach at Norfolk.**

| Material Used | Pyrethrins % | Date Oct. | Pounds per A. | Plants Examined | | Replications | Worms | |
|---|---|---|---|---|---|---|---|---|
| | | | | Size | No. | | No. | % Dead |
| Pyrocide-Talc 5% | 0.1 | 17 | 35–45 | Large | 2 | 1 | 115 | 83 |
| | | 17 | 35–45 | Small | 20 | 4 | 134 | 96 |
| | | 19 | 23–30 | Medium | 40 | 4 | 154 | 67 |
| | | 25 | 40–50 | Medium | 20 | 4 | 68 | 96 |
| | | 27 | 35–45 | Medium | 20 | 4 | 121 | 87 |
| Pyrocide-Talc 10% | 0.2 | 17 | 35–45 | Large | 2 | 1 | 78 | 96 |
| | | 17 | 35–45 | Small | 20 | 4 | 120 | 98 |
| | | 19 | 23–30 | Medium | 40 | 4 | 154 | 78 |
| | | 25 | 40–50 | Medium | 20 | 4 | 78 | 96 |
| | | 27 | 35–45 | Medium | 20 | 4 | 120 | 98 |
| Pyrocide-Talc 20% | 0.4 | 17 | 35–45 | Large | 2 | 1 | 109 | 100 |
| | | 17 | 35–45 | Small | 20 | 4 | 149 | 100 |
| | | 19 | 23–30 | Medium | 40 | 4 | 157 | 83 |
| | | 25 | 40–50 | Medium | 20 | 4 | 67 | 100 |
| | | 27 | 35–45 | Medium | 20 | 4 | 116 | 96 |
| Pyrocide-Sulphur 10% | 0.2 | 17 | 35–45 | Large | 2 | 1 | 72 | 97 |
| | | 17 | 35–45 | Small | 20 | 4 | 129 | 97 |
| | | 19 | 23–30 | Medium | 40 | 4 | 163 | 85 |
| | | 25 | 40–50 | Medium | 20 | 4 | 58 | 93 |
| | | 27 | 35–45 | Medium | 20 | 4 | 105 | 98 |
| Pyrethrum Powder-Talc | 0.2 | 19 | 23–30 | Medium | 40 | 4 | 145 | 83 |
| | | 25 | 40–50 | Medium | 20 | 4 | 82 | 96 |
| | | 27 | 35–45 | Medium | 20 | 4 | 111 | 93 |
| | 0.4 | 27 | 35–45 | Medium | 20 | 4 | 131 | 98 |
| Micronized Pyrethrum Sulfur-Clay | 0.123 | 25 | 40–50 | Medium | 20 | 4 | 74 | 77 |
| | | 27 | 35–45 | Medium | 20 | 4 | 121 | 60 |
| Micronized Pyrethrum-Silica | 0.123 | 25 | 40–50 | Medium | 20 | 4 | 69 | 92 |
| | | 27 | 35–45 | Medium | 20 | 4 | 138 | 82 |
| Untreated, Check | | 17 | | Large | | | 138 | 8 |
| | | 17 | | Small | | | 192 | 8 |
| | | 19 | | Medium | | | 218 | 25 |
| | | 25 | | Medium | | | 131 | 5 |
| | | 27 | | Medium | | | 149 | 13 |

of October 7 to determine whether the *Pyrocide* dust would be effective if applied when the plants were wet with dew. In this experiment, only 36 and 19 per cent of the webworms were killed by 60 and 35 pound applications of dust per acre compared with the 87 per cent kill obtained with both dosages applied on the previous day when the plants were dry.

Similar results were obtained in an experiment conducted on October 19 and 20, when two pyrethrum dusts applied in the evening of October 19 gave 84 and 69 per cent control as compared with 33 and 29 per cent control when they were applied early on the morning of October 20 while the plants were wet with dew.

PYRETHRIN CONTENT AND DOSAGE REQUIRED.—Several other tests were made with traction dusters equipped with a short canopy or trailer adjusted to confine the dust around the plants and prevent the wind from blowing the dust away before it settled. The results of these tests have been summarized and are given in table 1. The kills obtained were probably even higher than those indicated in the table because it was impossible to find all of the dead worms on the ground after treatment. This is indicated by the fact that more worms were found on the untreated check plants than on the treated ones.

When these data were analyzed sta-

tistically it was found that the number of dead worms was significantly greater in all the treated plats than in the untreated check plats. The micronized pyrethrum-tobacco-silica dust gave better results than the micronized pyrethrum-sulphur-clay dust but neither appeared to have a high enough pyrethrin content to give satisfactory results. The *Pyrocide* and pyrethrum powder dusts containing 0.2 per cent pyrethrins gave very high kills when applied at the rate of 35–45 pounds of dust per acre. Applications of these dusts at the rate of 23–30 pounds per acre were not as effective as at the heavier dosages. *Pyrocide* dust containing 0.1 per cent pyrethrins gave good results on small spinach when applied at the rate of 35–45 pounds per acre and in one test on medium sized spinach at the rate of 40–50 pounds per acre.

RESULTS OBTAINED BY COMMERCIAL GROWERS.—Numerous spinach growers used *Pyrocide* and pyrethrum powder dusts, containing 0.2 per cent pyrethrins, commercially, for the control of the Hawaiian beet webworm. As far as could be determined, all these growers were well pleased with the results obtained. The dusted spinach rapidly outgrew the webworm injury and produced good quality spinach, whereas the undusted early planted spinach was either destroyed or produced a low yield of poor quality.

One spray test was conducted for the control of the Hawaiian beet webworm on beets. A power sprayer delivering a pressure of 200 pounds per square inch with two nozzles per row was used for applying the sprays. In this test *Red Arrow* and *Evergreen*, commercially prepared pyrethrum sprays, used at a dilution of one part to 400 parts of water by volume gave good control.

Preliminary spray tests were conducted with *Red Arrow* and *Evergreen* on spinach but it was impossible to get satisfactory coverage of the undersides of the low growing spinach leaves and these tests were discontinued.

Since this work was completed it has been found that Roney (1937) reported excellent control of the Hawaiian beet webworm on beets from weekly applications of 25 pounds per acre of a pyrethrum-sulphur dust containing 0.1 per cent pyrethrins. Also in mimeographed paper Roney (1938) states that arsenicals and rotenone bearing dusts were relatively ineffective on beets.

CONCLUSIONS.—Calcium arsenate and rotenone bearing dusts were ineffective for the control of the Hawaiian beet webworm on spinach.

*Pyrocide* and pyrethrum powder dusts, containing 0.2 per cent pyrethrins, applied at the rate of 35 to 45 pounds of dust per acre gave very good control of the Hawaiian beet webworm on spinach when the plants were dry but failed to give satisfactory results when the plants were wet with dew.

*Red Arrow* and *Evergreen* gave good control of this webworm on beets.—11-16-39.

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# Pentatomids Attacking Tomatoes and Experiments on Their Control[1]

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During the late summer of 1939 growers and buyers of tomatoes in western New York were concerned about a yellowish discoloration that appeared on the fruit at ripening time. The blemishes were often referred to as cloudy spots. Tomatoes having these spots were undesirable to the canning trade and in many instances sold for fifty per cent less than fruit not so affected.

From observations in tomato plantings and studies of certain pentatomids caged with tomatoes, it was found that the injury above mentioned was the result

[1] Approved by the Director of the New York State Agr. Expt. Sta. for publications as Journal Paper No. 379.

of their feeding. Three species of pentatomids, namely, *Euschistis variolarius* Pal. de Beauv., *E. tristigmus* Says., and *Podisus maculiventris* Say. were found on tomato vines and fruit. The latter species is predaceous so probably is not responsible for injury to the fruit. *E. variolarius*

FIG. 1.—*Euschistus variolarius* adults feeding on ripe tomato.

was by far the most prevalent species, the nymphs of all instars as well as the adults having been observed feeding on the tomatoes. Ripe fruit seemed to be preferred but some individuals were observed to feed on half ripe fruit and a few on green tomatoes.

Injury to the tomato fruit results largely from the extraction of juices and the partial destruction of some of the fruit tissues. Apples and pears, when fed upon by closely related species of pentatomids, soon developed surface depressions of considerable size due to the collapse of tissues underlying the epidermis. The injured portion of the tomato, however, does not become depressed for some time especially if the fruit is attached to the plant and growing. However, if the fruit is separated from the plant and placed in a cage where the bugs can feed upon it the punctured areas soon develop into crater-shaped pits.

DESCRIPTION AND SEASONAL HISTORY.—The adult of *Euschistus variolarius* as seen in dorsal aspect is shield-shaped and brownish in color. It measures about 13 mm. in greatest length and about 7 mm. in greatest width. The head is somewhat triangular in appearance. The posterior angles of the pronotum are acute in some specimens, often reddish in color, and the legs are yellowish. A distinguishing mark of the male of this species is a large, circular black spot on the ventral aspect of the anal segment. The eggs are more or less barrel-shaped, measuring about 1.1 mm. in length and 1 mm. in diameter, and when first deposited are greenish-yellow in color, later becoming a dirty-yellow. The entire egg is covered with closely set, minute tubercles. A conspicuous characteristic of pentatomid eggs in general is the ring of chorial processes about the anterior pole or cephalic end. In the case of *E. variolarius* these whitish processes are of medium length as compared with those of *Podisus maculiventris* which are long and whip-like, and those of *Brochymena quadripustulata* Fab., which are flat and button-shaped.

The first instar nymphs appear grayish-green in color because of the more conspicuous greenish abdomen and the smaller, brownish thorax. The general shape as seen from above is oval, the posterior end being wider and more bluntly rounded than the anterior portion. The same body color persists in the second and third instars and to some extent in the fourth, but the thoracic region is increased in width at each successive instar until the fourth where it about equals the abdomen in transverse measurement. The color changes to brownish-black toward the end of this instar. The nymphs of the fifth stage are typically shield-shaped and become brownish in color.

The insects hibernate as adults but leave their shelter when the first warm days of spring arrive. Representatives of this species have been taken in the field as early as April 24. Some of these overwintering adults lived until the last of August. Members of this species occur on a great variety of plants, including trees, shrubs, bush fruits, and vegetables. The oviposition period as observed during the seasons of 1933 and 1934 extended from about May 24 to August 20. Individuals were seen to copulate for about an hour. As a rule the eggs are laid in masses consisting of several parallel rows and are securely fastened to the host by a cement-like material. The eggs occasionally may be scattered and solitary ones have been

found. They are deposited on green foliage or on any other object, and may be found on either the upper or lower leaf surface, most commonly on the latter.

The number of eggs in each mass, as noted in 1934, varied from 5 to 28. One female held in captivity laid 122 eggs in 6 separate masses: the first on July 31, the second on August 1, the third on August 4, the fourth on August 8, the fifth on August 11, and the sixth on August 15. The smallest mass contained 13 eggs and the largest 28. Eggs hatch in 4 to 8 days, averaging about 6 days. The duration of the several instars is as follows: The first, 4 to 7 days, averaging about 6 days; the second 6 to 18 days, averaging about 9.7 days; the third, 7 to 14 days, averaging about 10.3 days; the fourth, 7 to 16 days, averaging about 10.8 days; and the fifth 12 to 27 days, averaging 16.9 days.

CONTROL TESTS.—Two series of control tests were arranged during the latter part of August when the pest on tomatoes was first brought to the attention of the Department. In the first tests only dusts were used. These consisted of the following: *Dry Pyrocide*, containing 0.3 per cent pyrethrins; Derris, containing 1 per cent rotenone; and lime-nicotine dust containing 4 per cent nicotine. The second series of tests included one dust *Dry Pyrocide*, as described above, and three sprays. The amounts of materials for 100 gallons of spray were as follows: *D-X*, 1 quart; *Tox*, 1 quart; and nicotine sulfate, 1 quart, with soap, 3 pounds.

In carrying out the tests many pentatomids were collected from tomato plantings and separated into lots of from 23 to 41 bugs each. This distribution was so arranged that each group contained nymphs of each instar as well as adults. Fourth instar nymphs were the most plentiful in each lot. Those of the first and second instars were, in certain instances, represented by a single individual. A cylindrical, screened cage measuring approximately 18 inches in height and 6 inches in diameter was used to confine each lot of bugs during the test. Similar lots of bugs were placed in check cages. Only one method of applying the various materials was followed, namely, the dusts and sprays were driven through the screen onto the insects by hand-operated equipment. Each lot of bugs was subjected to a comparable application of the material to be tested. After the treatment the cage was jarred to remove excess spray or dust from the screen. Each cage was then placed in the shade where the air could circulate freely through it. The temperature during both series of tests was about 85 degrees F. Branches of tomato vines were put into the cages during the first series of tests, but no plant material was introduced during the second series. Observations of the insects in all cages were made directly after each test and each 24 hours thereafter. The bugs in the check cages were subjected to the same natural conditions as were those in the treated cages.

**Table 1.—Results of tests of various materials against pentatomids.**

| Materials | Number per Cage | Per Cent Dead During 120 Hours of Observation | | | | |
|---|---|---|---|---|---|---|
| | | 24 hrs. | 48 hrs. | 72 hrs. | 96 hrs. | 120 hrs. |
| **Test I** | | | | | | |
| Dust | | | | | | |
| *Dry Pyrocide* 0.3% pyrethrins | 30 | 37 | 63 | 87 | — | 93 |
| Derris, 1% rotenone | 28 | 14 | 14 | 21 | — | 39 |
| Lime-nicotine, 4% nicotine | 28 | 00 | 00 | 4 | — | 4 |
| Check | 41 | 5 | 12 | 17 | — | 29 |
| **Test II** | | | | | | |
| Dust | | | | | | |
| *Dry Pyrocide*, 0.3% pyrethrins | 23 | 65 | 87 | — | 87 | 87 |
| Spray | | | | | | |
| *D-X* 1–400 | 23 | 00 | 00 | — | 26 | 26 |
| *Tox* 1–400 | 23 | 4 | 9 | — | 9 | 9 |
| Soap, 3 lbs., Nicotine sulfate 1–400 | 23 | 00 | 9 | — | 9 | 9 |
| Check | 23 | 00 | 00 | — | 13 | 13 |

The results of the tests are shown in table 1. In the case of *Dry Pyrocide* practically all the bugs reached by the dust were either killed immediately or were so disabled that, except for feeble movements of the legs, they appeared dead. Eighty-seven per cent of the bugs showed no signs of life after 72 hours, and 93 per cent were dead after 120 hours. The next highest toxicity was shown by derris dust containing 1 per cent rotenone, but the number of individuals surviving after 120 hours was so great, 61 per cent, that this did not give control. The lime-nicotine dust killed only 4 per cent of the insects treated. The *Dry Pyrocide* was toxic to adults and nymphs alike. It will

be noted that this material gave almost identical results in the two tests under comparable conditions.

SUMMARY.—While the data here submitted are not extensive, the comparison of the results produced by the various dust and spray mixtures for the control of bugs injuring tomato fruits shows that *Dry Pyrocide* as used in these tests was much more toxic to this species of pentatomids than were any of the other materials applied. The difference in degree of toxicity of the insecticides tested is so great as to suggest *Dry Pyrocide* as a most promising material for control of these insects.—12-16-39.

## Notes on the Control of Onion Thrips

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The onion thrips (*Thrips tabaci* Lindeman) is frequently a serious pest on many different kinds of vegetable crops grown in the greenhouses at the Virginia Truck Experiment Station at Norfolk. In addition to dwarfing and even killing many plants, especially seedlings, this pest has greatly interfered with different types of experimental work. This has been especially true in plant breeding and soil deficiency studies because it has been difficult to determine which color variations and other plant changes were due to soil deficiencies and which were due to thrips injury.

None of the nicotine, pyrethrum, or rotenone sprays or dusts tested have given satisfactory control of the thrips in the greenhouse. Several of these materials gave good control of those actually hit at the time of treatment, but the plants soon became reinfested. Fumigation with cyanide at dosages strong enough to cause serious foliage injury on several different kinds of plants failed to control the insect.

Following the report of Nelson and Weigel (1939) that a tartar emetic-brown sugar solution would give good control of the gladiolus thrips, it was decided to test this material for the control of onion thrips in the greenhouse. The materials were applied as a fine mist through a *Touch Up Spray Gun* which is commonly sold by chain stores for use in connection with the air pressure from a spare tire. This spray gun was attached by means of a 30 foot rubber hose to an air pressure tank. The air pressure was adjusted to 15 pounds per square inch by means of a *Hoke* reducing valve.

For the first application in the first test on onions, potted plants were removed from the bench and treated individually and then replaced in the soil on the bench. In all subsequent tests the plants were not removed from the bench but were treated where they were growing, lots of from 6 to 10 plants replicated 3 times having been used. Each lot was enclosed during the time of treatment by cardboard barriers to prevent the drift of spray material from one lot to another undergoing different treatment.

TEST NUMBER ONE ON ONIONS.—In the first test on onions four treated lots were compared with an untreated lot. Three of the treatments were made with a mixture composed of 2 pounds of tartar emetic and 8 pounds of brown sugar in 50 gallons of water. Two of these had onion extracts added, one *Giroux Burnt Onion Sauce* (1–473) by volume) and the other, raw onion juice (1–118 by volume). The fourth treatment was made with a solution containing one part of a mixture of 80 per cent mineral oil and 20 per cent of a 5 per cent rotenone extract in a comphor sassafras base oil, emulsified with two parts of a potash cocoanut oil soap, in 400 parts of water.

Treatments were made on January 12 and 26, and by the end of January all of the onion plants in the tartar emetic-brown sugar treated lots had a normal green color and were free of thrips. The onion plants in the lots treated with the rotenone-oil emulsion were heavily infested and turning silver gray in color. The untreated plants were very severely injured by thrips.

TEST NUMBER TWO ON ONIONS.—By March 1 the onions which had been treated with the tartar emetic-brown sugar solution were becoming reinfested, so another test was made on some of the

same plants. In this test the plants sprayed with tartar emetic-brown sugar-*Giroux Burnt Onion Sauce* were treated again with the same material while the previously untreated check plants were treated with tartar emetic-brown sugar and those previously treated with tartar emetic-brown sugar became the new checks. These treatments were repeated on March 20 and 27, and April 6, and by the middle of April the tartar emetic-brown sugar treated plants, that had previously served as checks, had made a remarkable recovery from the thrips injury, while the new check plants had become seriously injured. The tartar emetic-brown sugar-*Giroux Burnt Onion Sauce* treated plants were free from injury.

TEST NUMBER THREE ON ONIONS.—During the latter part of January, onion sets were planted in two-inch pots which were embedded in the soil on a bench in the greenhouse. There were seven rows with six plants in each row.

On March 20 and 27, and April 6 and 14, every other row, starting with the outside row, was treated with tartar emetic-brown sugar (2-8-50). Thus four rows were treated and three rows were left as untreated checks.

A difference in the amount of thrips injury on the treated and untreated plants could be detected readily within a week after the first application. By April 10 the treated plants were more than twice the size of the untreated plants which were silver gray to white in color and severely wilted, as illustrated in figure 1.

The thrips infestation became much lighter by the end of April, as the insects were leaving the greenhouse for field crops. In harvesting the onions, on May 2, one outside row was abandoned so as to have an equal number of treated and untreated plants. One treated and one untreated plant had died of some undetermined disease, thus leaving 17 treated and 17 untreated. These plants were grown in cramped quarters; therefore none of them was large. However, the treated plants were almost large enough for table use and their average weight was 22.4 grams as compared to an average weight of 6.3 grams for the untreated plants, with odds of over 10,000 to one that these differences were due to treatment.

In a preliminary field test on onions a tartar emetic-brown sugar solution killed many of the thrips but it did not give as good control in the field as it did in the greenhouse.

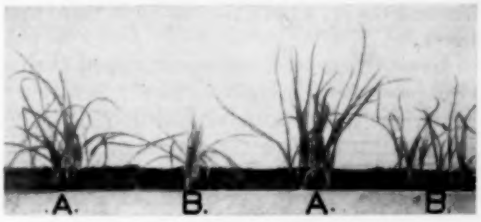


FIG. 1.—Thrips control on onions in the greenhouse effected by use of an atomized tartar emetic-brown sugar solution. A = Treated. B = Untreated.

TEST NUMBER ONE ON BEANS.—Snap beans planted in the greenhouse on February 28 had from 6 to 10 leaves and were heavily infested with thrips by March 20. At this time the plants were treated as follows: (1) tartar emetic-brown sugar (2-8-50); (2) tartar emetic-brown sugar (2-8-50) plus *Giroux Burnt Onion Sauce* (1-473); (3) untreated check lots. Each treatment was applied to 6 plants and replicated 3 times.

On March 25, counts were made of the number of living nymphs per leaf on two leaves from each plant, making a total of 36 leaves examined for each treatment and 36 for the untreated check. Treatments 1 and 2 had an average of 1.6 nymphs per leaf while the check had an average of 59.2. This is better than 97 per cent control for each treatment. The few nymphs on the treated leaves were practically all newly hatched and many appeared to be unhealthy, which would indicate a residual effect of the poison.

TEST NUMBER TWO ON BEANS.—On March 27 the beans were treated again in the same manner as on March 20. On April 4 counts were made of the number of live nymphs and adults remaining on 54 leaves from each treatment and 54 from the check. Treatments 1, 2, and 3 had an average of 0.2, 0.1, and 28.2 live nymphs and 0.6, 0.2, and 6.3 live adults per leaf, respectively. Both treatments gave over 99 per cent control of nymphs. Number 1 gave 91 per cent and number 2 gave 97 per cent control of adult thrips. The per cent control recorded for the adults is not as accurate as that for the

nymphs, as the adults were quite active and difficult to count. Also there was considerable migration of the adults.

It is of interest to note that many undetermined species of flies were found dead on the bean plants and on the ground around them, where the tartar emetic was used.

In addition to these results good thrips control was obtained in the greenhouse with the tartar emetic solution, and no foliage injury was observed, on the following plants: beets, cabbage, carrots, celery, collards, corn, egg-plant, kale, lettuce, lima beans, okra, onions, peanuts, peas, potatoes, snap beans, spinach, sweet potatoes, tomatoes, turnips, and watermelons.

SUMMARY.—In greenhouse tests, atomized tartar emetic-brown sugar solutions with or without burnt onion sauce or pure onion juice kept onion plants free of thrips injury, while plants treated with an emulsified oil-rotenone extract were severely injured. Plants left untreated for 20 days began to show signs of thrips injury. None of the spray materials injured the foliage. Onion plants treated four times with a tartar emetic-brown sugar solution produced an average yield of 22.4 grams per plant as compared to an average yield of 6.3 grams for untreated plants.

Tartar emetic-brown sugar solution did not give as good control of thrips on onions in the field as it did in the greenhouse.

One application of tartar emetic-brown sugar solution on snap beans heavily infested with onion thrips reduced the number of nymphs by more than 97 per cent and prevented reinfestation for at least 7 days.—11-16-39.

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# Dichloroethyl Ether for Wireworm Control[1]

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From 1936 to 1939 inclusive dichloroethyl ether has been tested under field conditions by the writer on vegetable crops infested with wireworms. The promising results presented in this paper are believed to be of possible value to other workers engaged in soil insect investigations.

Campbell and Stone (1935) found that dichloroethyl ether was highly toxic to wireworms in California. Snapp (1939) showed also that this material when sprayed on infested soil was highly toxic to larvae and pupae of the plum curculio, *Conotrachelus nenuphar* (Hbst.). The above investigators point out that concentrations which produced practically 100 per cent mortality of the insects caused no noticeable injury to growing plants. The properties of dichloroethyl ether are outlined by Snapp (1939).

METHODS.—Since wireworm infestations appear in localized areas in a field, all treatments were made after the insects began to feed on the roots of the growing crops. For clarity and convenience all dosages will be based on the quantities of the insecticide in a definite quantity of water applied to each plant or to each linear foot.

Although dichloroethyl ether is soluble in water to the extent of approximately 30 cc. per gallon, all material used in these experiments was emulsified with *Aresklene* or similar material to insure thorough distribution. The liquids in all experimental plots, were applied with measuring cups and measured accurately, while in commercial applications during 1939 they were poured from large (two to four quart) measuring pots and the quantity per plant was estimated.

Before the treatments were made the soil around the plants was prepared, by hoeing or by plowing, in such manner as to prevent excessive run-off of the liquid. Pepper (1937) discussed the importance of the wireworm problem in northern

[1] Paper of the Journal Series, New Jersey Agricultural Experiment Station, Department of Entomology.

New Jersey and also pointed out some of the limiting factors in protecting crops from injury by these insects.

PLOT ARRANGEMENTS.—In 1936 and 1937 all experiments were conducted on small scale plots of 50 to 100 plants each in order to determine plant tolerance as well as the toxicity of dichloroethyl ether to wireworms. All plots were duplicated in each experimental field and from 5 to 10 fields on different farms were used each year. In 1938 and 1939 larger plots were used. These consisted of from 4 to 10 rows through the infested area.

MORTALITY RECORDS.—The number of plants examined and the number of wireworms collected for mortality records depended on the size of the plots and the larval population. An attempt was always made to examine at least 50 wireworms in each treatment. A representative sample of treated plants was always left undisturbed for records of the effects of the treatments on the growing plants. It was found that at least 72 hours should elapse between the time of treatment and the recording of mortality. Although paralysis occurs immediately after the dichloroethyl ether comes in contact with the wireworms, some signs of life remain for two to three days. In taking samples for mortality records on the treatments in cabbage or cauliflower plantings, the count plant was removed and all the soil in a radius of 6 inches and to a depth of 6 inches was examined for larvae.

PLANT TOLERANCE.—Cabbage, cauliflower, kale and broccoli plants were set in a field free from wireworms, and treated with quantities of dichloroethyl ether ranging from 1 cc. to 10 cc. per plant in one-half pint of water. Each dilution was applied to triplicated plots. The dosage of 5 cc. of the ether per plant gave slight indications of stunting the growth but even the 10 cc. dilution did not completely kill the plants. Beets, swiss chard, and horse-radish showed no signs of injury from dosages of 5 cc. of dichloroethyl ether per pint of water applied on one linear foot of row space.

Tomato and cucumber appear to be susceptible to injury from a dose of 2 cc. per plant or hill.

We have evidence that dosages of 1 and 2 cc. of dichloroethyl ether per plant on cabbage, cauliflower and some other plants stimulate growth. Plants in the treated plots grew faster and became larger than the untreated and uninfested plants.

RESULTS.—The results summarized in table 1 were accumulated over a period of four years. These data need very little explanation other than to clear up some of the points that cannot be shown in tabular form. All living larvae observed in any of the treatments of 1 cc. or more dichloroethyl ether were 5 inches or more, laterally, from the base of the plants. In some cases, especially under very dry conditions, living larvae were found at depths of 6 or more inches, but under most conditions good vertical penetration of the chemical was obtained. This was determined by odor. Odor of dichloroethyl ether could be detected in the soil for a period of two weeks or more.

**Table 1.—A summary of four seasons' work with dichloroethyl ether for control of wireworms on cruciferous crops.**

| Dichloroethyl Ether per Plant (cc.) | Water per Plant | No. of Tests | No. of Wireworms | | Mortality Per Cent |
|---|---|---|---|---|---|
| | | | Examined | Dead | |
| 0.5 | .33 pt. | 2 | 184 | 101 | 54.8 |
| 1.0 | .33 pt. | 6 | 706 | 701 | 99.2 |
| 1.5 | .33 pt. | 6 | 915 | 911 | 99.5 |
| 2.0 | .33 pt. | 2 | 192 | 189 | 98.4 |
| 0.5 | .50 pt. | 3 | 237 | 162 | 68.3 |
| 1.0 | .50 pt. | 4 | 375 | 368 | 98.4 |
| 1.5 | .50 pt. | 1 | 102 | 100 | 98.0 |
| 2.0 | .50 pt. | 5 | 438 | 433 | 98.8 |
| 3.0 | .50 pt. | 4 | 225 | 225 | 100.0 |
| 4.0 | .50 pt. | 3 | 157 | 157 | 100.0 |
| 5.0 | .50 pt. | 2 | 136 | 135 | 99.2 |
| 1.0 | 1.00 pt. | 5 | 446 | 441 | 98.8 |
| 2.0 | 1.00 pt. | 2 | 109 | 108 | 99.1 |
| 5.0 | 1.00 pt. | 3 | 189 | 189 | 100.0 |
| 2.0 | None* | 2 | 167 | 67 | 40.1 |

* In this case the other was injected into the soil to a depth of 3 inches beside the plants.

The half cc. dosage failed to give adequate control while dosages of 1 cc. or more gave almost complete control on cabbage and related plants. The amount of water carrying the chemical apparently had little effect on the mortality of the insects, although when no water was used the mortality was only 40 per cent. In experiments on beets, swiss chard and horse-radish, where only one pint of water carrying 5 cc. of dichloroethyl ether was applied per linear foot of row, poor wetting of the soil immediately surrounding the roots resulted and consequently a low kill of wireworms was obtained. The information at hand and observations

made during the course of these experiments indicate that dichloroethyl ether, to be reasonably effective against wireworms and some other insects, must be in solution or in an emulsion. The material appears to be a very poor fumigant but an extremely toxic contact insecticide.

During the course of the wireworm studies it was noted that larvae and puparia of the cabbage maggot, larvae of the Japanese beetle, earthworms, and garden centipedes, were destroyed by the dichloroethyl ether treatments which were effective against wireworms.

During 1939 large plots of cabbage and cauliflower were treated commercially with dichloroethyl ether at the concentration of one fluid ounce per gallon of water, applying one-third of a pint of the liquid per plant. The wireworms were killed in these plots and a normal crop was harvested while approximately 50 per cent of the plants in the untreated sections of the field were destroyed by wireworms.—11-16-39.

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# The Metabolism in the Corn Earworm[1]

## *III. Weight, Water, and Diapause*

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The object of the study of metabolism of the corn earworm, *Heliothis armigera* (Hubn.), is to determine the effect of primary environmental factors, food, temperature, and humidity, on its development, chemical constitution, and behavior, with particular regard to winter survival. As the insect winters in the pupal stage it follows that the chemical constitution of full grown larvae (prepupae) and of pupae is of most concern. The first part of the study is devoted primarily to gross or basic chemical analyses; *i.e.*, total fat, carbohydrate, protein, and minerals. These analyses and observations are expected to form a background for specialized studies of particular metabolic functions.

The order in which various phases of the project will be undertaken will depend upon available equipment and developments. Observations on fat and glycogen have been published; the present paper treats of the weight of mature larvae and pupae and of the water content of their bodies. As the water in the insect's body supposedly plays an important role in cold hardiness, it is logical that both be considered at the same time. The diapause phenomenon observed during the experiments is also considered, particularly since it appears, in turn, to be interrelated with cold hardiness.

It seems wise to define some of the terms as used in this paper. Diapause is the state of an insect during which development has been spontaneously arrested and metabolism proceeds at a greatly reduced rate. Dormancy and diapause for the present will be considered as synonyms, although it may appear from future developments that diapause is a more specific term. In the corn ear worm, diapause occurs early in the pupal stage, but an individual in diapause can be distinguished only by its inability to develop within a given time at a given constant temperature. At 18.9 degrees[4] pupae in diapause can be separated from others with reasonable accuracy at 15 days and with certainty at 17 days. At this time there is evident development

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[4] All temperatures are Centigrade.

of wing pads as viewed through the pupal skin of active pupae. Cold hardiness is the ability of an insect to survive exposure to subzero temperatures, and hardening is the process by which an insect conditions itself to withstand cold temperatures.

Literature relating to water metabolism, winter hardiness, and diapause has been summarized by Uvarov (1931) and will not be elaborated on at this time.

The work reported in this paper was done during 1938 and 1939. In securing the results reported here, more than 5,000 insects were used and more than 12,000 weighings were necessary. In excess of 800 individual moisture determinations, 1,200 undercooling and freezing point observations, and 250 unfreezable water determinations were made.

METHODS.—The general plan of the experiment was to rear larvae on very young[5] sweet corn and on late dough stage[6] sweet corn at temperatures of 13.3, 18.9, 24.4, and 30 degrees; because of the high mortality in the pupal stage, incubation at 13.3 degrees was discontinued. Prepupae were kept at the same series of temperatures, some in wet soil (18 to 25 per cent water) and some in very dry soil (1 to 2 per cent water). Pupae were also kept at the above temperatures (except when hardening was attempted in the refrigerator) at humidities ranging from zero to approximately 100 per cent.

The insects reared were divided into four groups: (1) those on which observations were made on the effect of the above factors on live weight of mature larvae and of pupae and on loss of weight during the pupal period; (2) those on which determinations of moisture content were made in order to correlate water content with food of larvae, with soil moisture during the prepupal period, and with humidity and loss of weight during the pupal period; (3) insects reared to determine factors influencing diapause; and (4) those on which measurements of indices of cold hardiness (undercooling and freezing points and freezable water) were made.

The details of handling larvae and prepupae have already been described (Ditman, 1938). Constant temperatures were maintained in a battery of four incubators equipped with refrigerating mechanism and a mechanical refrigerator was used for low temperatures. Humidities were maintained with saturated salt solutions, which proved more satisfactory than sulfuric acid since they do not change concentrations over periods of time. However, they have the disadvantage of giving slight uncontrollable variations in humidity at different temperatures, depending on the solubility of the salt. Magnesium chloride was used for 32–33 per cent, calcium nitrate for 46–55 per cent, and sodium chloride for 75–76 per cent humidities; anhydrous calcium chloride was used for approximately zero humidity and water for approximately 100 per cent humidity. Desiccators and stender dishes (low form) constituted humidifiers in which pupae were placed in especially constructed racks.

In making live-weight studies, individual insects were weighed at definite time intervals. For moisture studies during the pupal period, duplicate samples composed usually of four pupae were run, and each of the newly formed pupae was weighed individually. At the desired time, for moisture determination, the surviving insects were weighed as a group and the original weight of any dead insect was discarded. Moisture was determined by drying to constant weight at 40 degrees *in vacuo*.

Undercooling and freezing points were determined by the thermocouple method (Robinson, 1927). A type K potentiometer and a type R galvanometer were utilized and temperatures were taken by placing the thermocouple against the insect. Each holder was made of a cork split longitudinally into three pieces, two of which were hollowed out to make a cell. The cell was lined with lamb's wool to hold the insect firmly but not tightly, and the thermocouple was so placed in the third piece that, when all were put together, the thermocouple rested against the insect. Dry ice in gasoline provided the cooling medium, and the temperature of the bath was usually maintained 10 to 15 degrees below the expected undercooling point.

The calorimeter, or heat of fusion, method was used for the measurement of freezable water. The home-made dry ice refrigerator devised for maintaining the required subzero temperature will be

[5] 10 to 14 days after silking.
[6] 30 to 50 days after silking.

described elsewhere. A Beckman differential thermometer was used in a dewar flask, 10 by 2½ inches (outside measurements), which, with stirring mechanism, constituted the calorimeter. Three or four insects (1 to 2 grams) composed a sample, and 50 cubic centimeters of water was used directly in the dewar flask.

The formula used by Greathouse (1935) was adapted and used rather than that suggested by Robinson (1927 a):

$$W_i = \frac{FN_w'(T_2-T_2) - [W_tS_t(T_3-T_1)+W_dS_d(T_3-T_1)+W_wS_w(T_3-T_1)]}{H_f-(S_b-S_i)(T_\Delta-T_1)}$$

Where (constants found for this experiment in parentheses):

$W_i$ = Weight of ice to be calculated
$F$ = Calorimeter factor (1.16)
$N$ = Grams water in calorimeter (50)
$S_w'$ = Specific heat of water between calorimeter temperatures.
$(T_3-T_2)$ = Change of temperature in calorimeter
$W_t$ = Weight of tin insect containers
$S_t$ = Specific heat of tin
$(T_3-T_1)$ = Change in temperature of sample from ice box to equilibrium in calorimeter
$W_d$ Weight of dry matter
$S_d$ = Specific heat of dry matter (.49)
$W_w$ = Weight of total moisture in sample (determined for each sample)
$H_f$ = Heat of fusion of ice
$S_b$ = Specific heat of unfreezable water (assumed same as water, average value over temperature range used = 1.007)
$S_i$ = Specific heat of ice from ice box, temperature, −19.3 degrees to freezing point of water (.505)
$T_\Delta$ = Freezing point of sample (determined by thermocouple, see undercooling)
$T_i$ = Lowest temperature of frozen sample (−19.3±0.1 degrees)

For further information on the calorimetric method for determining freezable water, consult Greathouse and Robinson.

Cold hardening of diapausing and nondiapausing insects was attempted by both continuous and discontinuous exposures at −2 to +4 degrees in a mechanical refrigerator.

## RESULTS

FACTORS INFLUENCING SIZE OF PUPAE.—Food and temperature during the larval period and soil moisture appear to influence the size of pupae (Table 1). In table 1, only a part of the results secured are reported, but they are sufficient to show the relationships observed. Males tend to be heavier than females except where prepupae are placed in dry soil.

In general, the larvae reared at 24.4 degrees were larger than those reared at 30 degrees. The larvae were fed in containers (3-ounce tin boxes) which were sterilized daily; if fed less often, normal development did not always take place. apparently, carbon dioxide from yeast developing in the corn accumulated, sometimes in sufficient amounts to suffocate the insects if containers and food were not changed.

LOSS OF WEIGHT DURING THE PREPUPAL STAGE.—The prepupal stage is spent in the soil and is characterized by rapid reduction in the size of the larva from the time it ceases feeding until the pupa is formed. Soil moisture was found to play a considerable part in the extent of this size reduction (Tables 1 and 2). At 18.9 degrees, pupation was never successful in dry soil (1 to 2 per cent water). At 13.3 degrees, pupation was never successful in dry soil and only occasionally in moist soil. Increased weight loss in dry soil at 18.9 degrees is probably the result of longer exposure of the prepupae to the dehydrating conditions.

It is difficult to give the loss of weight of prepupae as the exact beginning of the

**Table 1.—Some factors affecting the size of pupae.**

| Food—Corn in: | Temp. | Prepupae in: | Male | | Female | |
|---|---|---|---|---|---|---|
| | | | Number | Ave. wt. grams | Number | Ave. wt. grams |
| Milk stage | 30.0° | Wet soil | 197 | .4488 | 218 | .4456 |
| Dough stage | 30.0 | Wet soil | 73 | .4560 | 80 | .4367 |
| Milk stage | 30.0 | Dry soil | 53 | .3990 | 42 | .4255 |
| Milk stage | 24.4 | Wet soil | 164 | .4662 | 152 | .4619 |
| Dough stage | 24.4 | Wet soil | 76 | .4654 | 66 | .4593 |
| Milk stage | 24.4 | Dry soil | 41 | .4078 | 34 | .4202 |
| Milk stage | 18.9 | Wet soil | 8 | .4474 | 3 | .4647 |
| Dough stage | 18.9 | Wet soil | 5 | .4934 | 6 | .4729 |

**Table 2.—The effect of soil moisture on loss of weight during the prepupal period for mixed sexes.**

| Food—Corn in: | Temp. | Soil Moisture | Period: Days | Number of Insects | Ave. Loss—Weight | |
|---|---|---|---|---|---|---|
| | | | | | Grams | Per Cent |
| Milk stage | 30.0° | Wet | 2 | 19 | 0.060 | 13.2 |
| Dough stage | 30.0 | Wet | 2 | 14 | 0.068 | 12.2 |
| Milk stage | 30.0 | Dry | 2 | 10 | 0.106 | 21.7 |
| Dough stage | 30.0 | Dry | 2 | 10 | 0.112 | 20.7 |
| Milk stage | 24.4 | Wet | 3 | 21 | 0.075 | 15.0 |
| Dough stage | 24.4 | Wet | 3 | 7 | 0.034 | 6.3 |
| Milk stage | 24.4 | Dry | 3 | 12 | 0.087 | 18.8 |
| Dough stage | 24.4 | Dry | 3 | 6 | 0.122 | 22.8 |
| Milk stage | 18.9 | Wet | 6 | 16 | 0.050 | 10.9 |
| Milk stage | 18.9 | Dry | 6 | 14 | 0.159 | 33.0 |

prepupal period is not clearly marked. The results are given for definite periods preceding pupation.

LOSS OF WEIGHT DURING PUPAL STAGE.—It was found that the rate of loss of weight during the pupal period

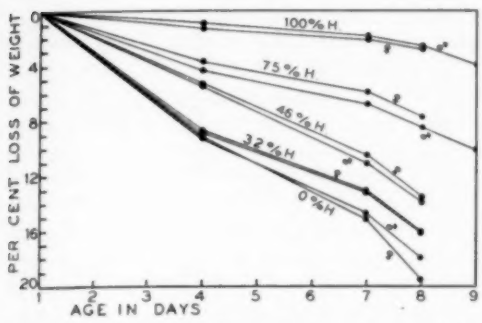


FIG. 1.—Effect of humidity on the rate of weight loss by pupae at 30 degrees from larvae reared on milk stage corn at 30 degrees, prepupae in moist soil (H. = humidity).

was influenced by humidity or soil moisture. The effect of humidity on the rate of weight loss is shown in figures 1 to 5. These results are based on series weighings of individual pupae, 16 pupae usually constituting a sample. The results shown in the figures are not measurements of total loss because of variations in emergence dates; total average loss of weight from time of pupation to emergence for the several humidities and temperatures is given in table 3.

**Table 3.—Percentage of weight lost during the pupal period for pupae kept under different temperatures and humidities.**

| | PER CENT WEIGHT LOST | | | | |
|---|---|---|---|---|---|
| | 30° | | 24.4° | | 18.9° |
| HUMIDITY APPROX. | Male | Female | Male | Female | Mixed sexes |
| | Food: milk stage corn | | | | |
| 100% | 3.0 | 3.0 | 1.9 | 2.6 | 2.8 |
| 75 | 11.2 | 9.3 | 10.5 | 10.5 | 19.6 |
| 55 | 16.9 | 15.2 | 13.2 | 12.9 | —* |
| 32 | 21.6 | 19.2 | 19.2 | 18.1 | 31.6 |
| 0 | 21.6 | 21.4 | 25.8 | 24.6 | 39.2 |
| | Food: dough stage corn | | | | |
| 100% | 1.6 | 1.3 | 2.1 | 1.9 | 3.8 |
| 75 | 14.7 | 14.6 | 14.4 | 11.8 | —* |
| 55 | 18.5 | 19.1 | —* | —* | —* |
| 32 | 22.7 | 18.7 | 22.1 | 19.1 | 21.3 |
| 0 | 18.6 | 18.6 | 19.9 | 16.9 | —* |

* Indicates death of all specimens or a number of survivors too small for significant results.

At 18.9 degrees, pupae usually became dehydrated to the point of death at zero and 30 per cent humidities; apparently normal moths emerged from pupae which had lost up to 20 per cent of their weight but when 25 per cent or more weight was lost most of the pupae died before moths emerged. Interesting is the ability of dormant or diapausing individuals to

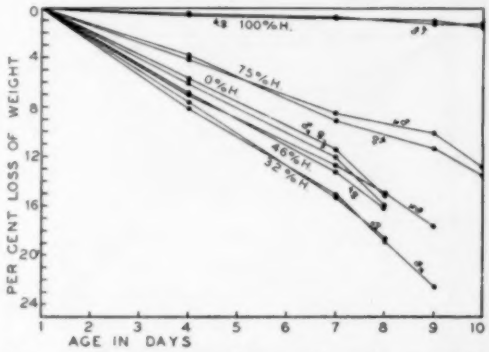


FIG. 2.—Effect of humidity on the rate of weight loss by pupae at 30 degrees from larvae reared on dough stage corn at 30 degrees, prepupae in moist soil (H. = humidity).

maintain their weight. Diapausing pupae, from larvae reared on milk stage corn at 100 per cent humidity, lost only 1.4 per cent of their weight in 85 days; at 75 per cent, similar pupae lost only 3.9 per cent in the same period.

Pupae in diapause from larvae reared on dough stage corn kept at 100 per cent

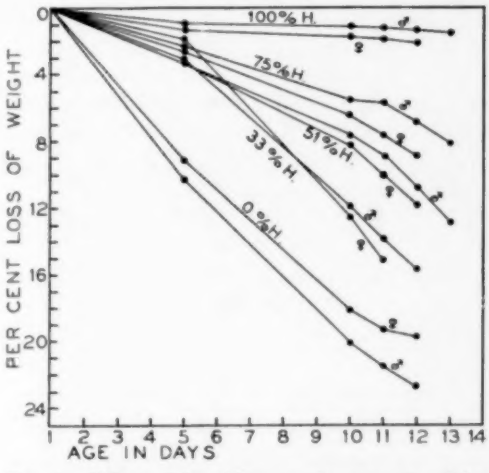


FIG. 3.—Effect of humidity on the rate of weight loss by pupae at 24.4 degrees from larvae reared on milk stage corn at 24.4 degrees, prepupae in moist soil (H. = humidity).

humidity for 65 days lost 1.3 per cent of their weight. There were no such pupae among the groups reared for study of loss

of weight at 18.9 degrees, and zero and 30 per cent humidities, but in later groups of pupae in 30 per cent humidity at 18.9 degrees, individuals in diapause did occur and were observed to be in a strong, healthy condition when active individuals had dehydrated to a fatal extent.

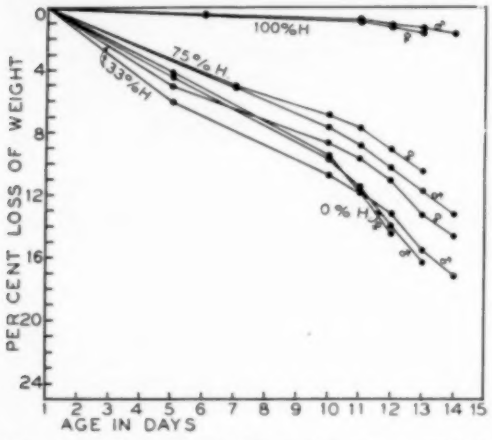


FIG. 4.—Effect of humidity on the rate of weight loss by pupae at 24.4 degrees from larvae reared on dough stage corn at 24.4 degrees, prepupae in moist soil (H. = humidity).

Results of observations on loss of weight in soils of different moisture content are complicated because of the difference in water holding capacity of various kinds of soil. The types of soil used in this experiment varied somewhat but were, in general, heavy sandy loam. The greatest loss of weight was by pupae reared on dough stage corn at 24.4 degrees and kept in dry soil. All pupae in wet and dry soil lost weight except those in wet soil at 18.9 degrees; here they gained 0.6 per cent in weight during the period. The effect of soil moisture on loss of weight of pupae is given in table 4.

**Table 4.—The effect of soil moisture on loss of weight during the pupal period.**

| Food.—Corn in: | Temp. | Soil Moisture | Number Insects | Weight Lost |
|---|---|---|---|---|
| Milk stage | 30.0° | Wet | 6 | 1.9% |
| Milk stage | 30.0 | Dry | 9 | 12.4 |
| Dough stage | 30.0 | Wet | 14 | 1.1 |
| Dough stage | 30.0 | Dry | 9 | 16.4 |
| Milk stage | 24.4 | Wet | 17 | 1.7 |
| Milk stage | 24.4 | Dry | 15 | 11.8 |
| Dough stage | 24.4 | Wet | 7 | 0.7 |
| Dough stage | 24.4 | Dry | 5 | 17.3 |
| Milk stage | 18.9 | Wet | 12 | 0.6 |

More interesting are the attempts to rehydrate dehydrated pupae. One series of 17 pupae reared on milk stage corn (prepupae in wet soil) at 30 degrees was placed in dry soil for five days during which time they lost an average of 0.038 gram, or 0.007 gram per day. They were then put in wet soil until emergence during which time they lost an average of 0.001 gram. Another series of 19 pupae, reared under the same conditions, was placed on dry soil five days during which time they lost an average of 0.019 gram. They were then placed on wet cotton in such a manner that they were partly submerged in water until emergence during which time they gained an average of 0.0005 gram. Of a third series at 30 degrees, in which the prepupae had been put in dry soil, the pupae at one day of age were placed on wet cotton so as to be partly submerged in water. These 13 pupae gained an average of only 0.0009 gram until emergence. A series of pupae treated in a manner similar to the last, except at 24.4 degrees, where they were exposed longer to the moist condition, gained an average of 0.004 gram during the entire pupal period.

Another group of pupae from larvae reared on milk stage corn at 30 degrees was placed in the refrigerator at 5 degrees. When for a period of 40 days they were alternately placed 10 days in dry soil and then 10 days partly submerged on wet cotton, eight male pupae lost an average of 0.009 gram during the first 10-day period in dry soil. They gained an average of 0.001 gram during the following 10-day period in wet cotton. Again, in dry soil they lost an average of 0.018

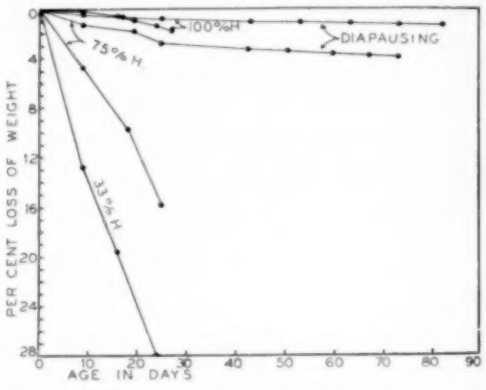


FIG. 5.—Effect of humidity on the rate of weight loss by pupae at 18.9 degrees from larvae reared on milk stage corn at 18.9 degrees, prepupae in moist soil (H. = humidity).

**Table 5.—The relation between weight loss and percentage water during the pupal period at 30 degrees and 32 and 100 per cent humidities from larvae reared on dough stage corn and milk stage corn, prepupae in moist soil.**

| | | | 4 DAYS | | 7 DAYS | | 8 DAYS | | 9 DAYS | |
|---|---|---|---|---|---|---|---|---|---|---|
| FOOD.—CORN IN: | HUMIDITY | SEX | Weight Lost | Water | Weight Lost | Water | Weight Lost | Water | Weight Lost | Water |
| Milk stage | 100% | M | 0.7% | 66.2% | 2.1% | 69.1% | 1.1% | 70.2% | 1.4% | 70.5% |
| Milk stage | 100 | F | 0.7 | 66.0 | 3.1 | 67.1 | 0.1 | 67.1 | 1.1 | 68.7 |
| Milk stage | 32 | M | 9.1 | 64.7 | 18.0 | 62.2 | 18.5 | 63.5 | 25.2 | 63.5 |
| Milk stage | 32 | F | 7.5 | 64.1 | 15.6 | 61.2 | 16.2 | 62.3 | 30.0 | 59.4 |
| Dough stage | 100 | M | 0.5 | 66.0 | 10.1 | 64.2 | 1.3 | 69.5 | 1.3 | 63.6 |
| Dough stage | 100 | F | 1.6 | 65.0 | 9.5 | 63.2 | 11.9 | 64.8 | 1.8 | 30.7 |
| Dough stage | 32 | M | 16.4 | 65.8 | 32.4 | 67.5 | | | | |
| Dough stage | 32 | F | 10.2 | 64.8 | 21.2 | 59.8 | 20.2 | 61.0 | 19.9 | 60.4 |

gram in ten days. They gained 0.003 gram in the second period on wet cotton. Seven females treated in the same manner lost an average of 0.012 gram during the first dry period, gained an average of 0.0002 gram during the first period in wet cotton. They lost an average of 0.020 gram during the second period in dry soil and gained 0.001 gram during the final period in wet cotton. It seems evident from these experiments that dehydration takes place more readily than rehydration and it is not certain if water taken up by pupae ever serves a metabolic role. It was found that once a pupa has been dehydrated to a point near death it will not take up sufficient water, even though partly submerged, to give rise to a normal moth. Water seems to be absorbed by the pupal skin and absorption was observed to be most rapid near the end of the pupal period. Moths emerging from pupae on wet cotton usually had a water-soaked appearance and some of them died in the pupal skin. Pupae not giving rise to normal moths were not included in the results in the preceding paragraph.

MOISTURE DURING PREPUPAL PERIOD —Moisture decreased both in amount and in per cent during the prepupal period. Because of difficulty in estimating the age of prepupae, figures on the rate of water loss are approximate. Observations on a number of moisture determinations show that in larvae reared on milk stage corn, the per cent of moisture at the beginning of the prepupal period was over 70; when these prepupae were kept in moist soil at 30 degrees, their moisture dropped to as little as 68 per cent just before pupation, and in dry soil to 67 per cent or less. Prepupae from larvae fed on dough stage corn contained 1 to 3 per cent less water but showed similar reductions in water content. There seemed to be very little difference in rate of water loss under wet soil condition at the three temperatures used. In dry soil more water was lost as the temperature was lowered. By selection of food during the larval period, and by choice of temperature and soil moisture during the prepupal period, the water content of resulting pupae can be varied from 61 to 69 per cent in females and

**Table 6.—The relation between weight loss and percentage of water during the pupal period at 24.4 degrees and 32 and 100 per cent humidities from larvae reared on dough stage and milk stage corn, prepupae in moist soil.**

| | | | 5 DAYS | | 10 DAYS | | 11 DAYS | | 12 DAYS | |
|---|---|---|---|---|---|---|---|---|---|---|
| FOOD.—CORN IN: | HUMIDITY | SEX | Weight Lost | Water | Weight Lost | Water | Weight Lost | Water | Weight Lost | Water |
| Milk stage | 100% | M | 0.6% | 69.0% | 1.0% | 67.8% | 2.1% | 70.5% | 1.6% | 67.2% |
| Milk stage | 100 | F | 0.5 | 68.4 | 1.0 | 69.0 | 1.0 | 67.4 | 2.8 | 70.3 |
| Milk stage | 32 | M | 5.6 | 66.8 | 17.2 | 63.4 | 23.9 | 64.5 | 23.3 | 63.9 |
| Milk stage | 32 | F | 4.3 | 65.7 | 16.0 | 61.6 | 18.2 | 61.3 | 25.8 | 61.3 |
| Dough stage | 100 | M | 1.6 | 63.5 | 1.7 | 64.0 | 2.7 | 69.1 | 3.0 | 68.8 |
| Dough stage | 100 | F | 2.0 | 65.2 | 1.8 | 64.6 | 3.3 | 66.7 | 2.9 | 65.8 |
| Dough stage | 32 | M | 6.2 | 66.2 | 14.8 | 61.5 | 22.1 | 58.1 | 23.5 | 58.4 |
| Dough stage | 32 | F | 5.5 | 64.9 | 18.0 | 61.7 | 21.2 | 56.9 | 22.4 | 59.9 |

from 64 to 71 per cent in the male pupae.

MOISTURE DURING THE PUPAL PERIOD.—The loss of weight and loss of moisture content can be more closely associated during the pupal period than during the prepupal period as the exact age of pupae can be reckoned. Series of pupae were individually weighed and kept under known conditions of temperature and humidity for definite periods, then reweighed and their moisture content determined. Pupae reared on milk stage corn were kept at 100, 75, 55, 32, and zero per cent humidities and at temperatures of 30 and 24.4 degrees. Four series of pupae from larvae reared on dough stage corn were kept at 100 and 32 per cent humidities and at 24.4 and 30 degrees. There were also groups in dry soil at these two temperatures. The results of the 8 series in 100 and 32 per cent humidities and at 24.4 and 30 degrees from larvae reared on dough and milk stage corn appear in tables 5 and 6.

**Table 7.—Observations on the effect of temperature on the diapause phenomenon.**

| TREATMENT | NUMBER PUPAE | NUMBER IN DIAPAUSE |
|---|---|---|
| Larvae reared at 18.9 degrees on milk stage corn, prepupae in wet soil at 18.9 degrees, pupae at 100 per cent humidity at 18.9 degrees | 149 | 17 |
| Larvae reared at 18.9 degrees on dough stage corn, prepupae at 18.9 degrees in wet soil, pupae at 100 per cent humidity at 18.9 degrees | 75 | 34 |
| Larvae reared at 18.9 degrees on milk stage corn, prepupae in wet soil at 18.9 degrees, pupae at 30 per cent humidity at 18.9 degrees | 30 | 3 |
| Larvae reared at 18.9 degrees on milk stage corn, prepupae in wet soil at 18.9 degrees, pupae at 75 per cent humidity at 18.9 degrees | 11 | 6 |
| Larvae reared on dough stage corn at 30 degrees, prepupae in moist soil at 30 degrees, pupae at 100 per cent humidity at 18.9 degrees | 16 | 0 |
| Larvae reared on milk stage corn at 30 degrees, prepupae in moist soil at 30 degrees, pupae at 100 per cent humidity at 18.9 degrees | 16 | 0 |
| Larvae reared on milk stage corn at 30 degrees, prepupae in dry soil at 30 degrees, pupae at 100 per cent humidity at 18.9 degrees | 16 | 0 |
| Larvae reared on dough stage corn at 30 degrees, prepupae in dry soil at 30 degrees, pupae at 100 per cent humidity at 18.9 degrees | 14 | 0 |
| Larvae reared on milk stage corn at 30 degrees, prepupae in moist soil at 18.9 degrees, pupae at 100 per cent humidity at 18.9 degrees | 16 | 0 |
| Larvae reared on dough stage corn at 30 degrees, prepupae in moist soil at 18.9 degrees, pupae at 100 per cent humidity at 18.9 degrees | 16 | 0 |
| Larvae reared on dough stage corn at 24.4 degrees, prepupae in moist soil at 24.4 degrees, pupae at 100 per cent humidity at 18.9 degrees | 16 | 0 |
| Larvae reared on milk stage corn at 24.4 degrees, prepupae in moist soil at 24.4 degrees, pupae at 100 per cent humidity at 18.9 degrees | 15 | 0 |
| Larvae reared on dough stage corn at 18.9 degrees, prepupae in moist soil at 18.9 degrees, pupae at 100 per cent humidity at 30 degrees | 13 | 0 |
| Larvae reared on milk stage corn at 18.9 degrees, prepupae in moist soil at 18.9 degrees, pupae at 100 per cent humidity at 30 degrees | 16 | 2 |
| Larvae reared on milk stage corn at 30 degrees, prepupae in moist soil at 5 degrees for 6 days then at 18.9 degrees, pupae at 100 per cent humidity at 18.9 degrees | 16 | 1 |
| Larvae reared on dough stage corn at 30 degrees, prepupae in moist soil at 5 degrees for 6 days then at 18.9 degrees, pupae at 100 per cent humidity at 18.9 degrees | 12 | 3 |

It was observed in these moisture and loss of weight determinations that in normal pupae the water content varied between 60 and 72 per cent. When the moisture content dropped much below 60 per cent, moths either died in the pupal skin or emerged in an abnormal condition. When moisture approached 55 per cent, death followed. The moisture content was lower in pupae from larvae fed on dough stage corn than in those fed on milk stage corn, lower in pupae from prepupae in dry soil than in wet soil, and lower in females than in males.

A limited number of observations on weight loss and per cent water at 18.9 degrees indicates the same degree of variation as observed at 24.4 and 30 degrees, except that the loss of weight at low humidity was greater, usually resulting in death of pupae although abnormal moths sometimes emerged. Series of pupae in dry soil at 24.4 and 30 degrees lost considerable weight but the moisture content of pupae never dropped below 60 per cent.

DIAPAUSE.—The corn ear worm overwinters in the pupal stage and it is in this stage that diapause appears. Probably the most interesting contribution in this paper is the relationship of ecological factors and diapause. In nine years' experience of rearing ear worm larvae at 30 degrees on dough stage corn, milk stage corn, tomatoes, and beans, a pupa in diapause was never observed. For two years, large numbers of larvae were reared at 18.9, 24.4, and 30 degrees on dough stage and milk stage corn; during this period pupae in diapause were observed, in some lots as high as 50 per cent at 18.9 degrees, never at 24.4 or 30 degrees. In order to determine at what stage of development temperature was responsible for the stimulation of diapause, groups of

**Table 8.—Undercooling and freezing points and per cent water of pupae at 32 and 100 per cent humidities and 30 degrees from larvae reared on dough stage and milk stage corn.**

| FOOD.—CORN IN: | HUMIDITY | AGE (days) | MALE | | | FEMALE | | |
|---|---|---|---|---|---|---|---|---|
| | | | Water | Undercooling Temp. | Freezing Temp. | Water | Undercooling Temp. | Freezing Temp. |
| Milk stage | | 1 | 67.1% | −16.5° | − 8.1° | 65.9% | −19.5° | − 9.4° |
| Milk stage | 100% | 4 | 69.1 | −21.9 | −11.4 | 65.1 | −21.7 | −11.4 |
| Milk stage | 100 | 7 | 69.4 | −23.2 | −13.6 | 70.0 | −21.8 | −11.3 |
| Milk stage | 100 | 8 | 69.0 | −25.4 | −16.0 | 69.4 | −22.9 | −13.6 |
| Milk stage | 100 | 9 | | −16.0 | − 8.0 | 67.0 | −19.2 | −10.8 |
| Milk stage | 32 | 4 | 65.3 | −19.6 | −11.3 | 60.5 | −19.9 | −11.3 |
| Milk stage | 32 | 7 | 61.1 | −15.8 | − 7.4 | 61.9 | −20.5 | −12.0 |
| Milk stage | 32 | 8 | 62.9 | −21.9 | −10.9 | 61.8 | −23.0 | −13.0 |
| Milk stage | 32 | 9 | 68.1 | −22.2 | −11.7 | 61.7 | −21.8 | −10.1 |
| Dough stage | | 1 | 66.7 | −19.7 | − 9.2 | | −17.4 | − 7.4 |
| Dough stage | 100 | 4 | 68.8 | −18.1 | − 7.6 | 65.5 | −18.1 | − 9.0 |
| Dough stage | 100 | 7 | 67.8 | −19.1 | −10.2 | 67.9 | −19.2 | − 8.4 |
| Dough stage | 100 | 8 | 69.2 | −18.2 | − 8.8 | 66.8 | −16.6 | − 8.5 |
| Dough stage | 100 | 9 | 66.1 | −16.9 | − 7.8 | | | |
| Dough stage | 32 | 4 | | −20.5 | −12.9 | 64.1 | −19.8 | −12.3 |
| Dough stage | 32 | 7 | 69.6 | −20.9 | −11.6 | 63.1 | −20.7 | −10.0 |
| Dough stage | 32 | 8 | 66.0 | −20.5 | −10.0 | 61.7 | −21.6 | −10.7 |
| Dough stage | 32 | 9 | 63.3 | −18.0 | − 9.4 | 60.5 | −20.0 | −10.2 |

larvae were reared at the different temperatures available and changed at various periods to lower or higher temperatures. The results of these experiments are given in table 7. The role of temperature during the larval and prepupal periods in causing diapause during the pupal period is evident. Neither the water content of pupae nor the age of corn on which larvae were fed appeared to exert any influence on the tendency of pupae to enter diapause. Water content of normal-appearing pupae in diapause varied from 62 to 68 per cent. During 1938 a larger percentage of pupae in diapause appeared among those reared from larvae fed on milk stage than on dough stage corn; during 1939 the reverse was true.

WINTER HARDINESS.—Now that it has been found that water content of normal pupae varies as much as 10 per cent (60 to 70 per cent) and that pupae which later undergo diapause are produced when larvae feed at temperatures of about 18.9

**Table 9.—Undercooling and freezing points and per cent water of pupae at 32 and 100 per cent humidities and 24.4 degrees from larvae reared on dough stage and milk stage corn, prepupae in moist soil.**

| FOOD.—CORN IN: | HUMIDITY | AGE (days) | MALE | | | FEMALE | | |
|---|---|---|---|---|---|---|---|---|
| | | | Water | Undercooling Temp. | Freezing Temp. | Water | Undercooling Temp. | Freezing Temp. |
| Milk stage | | 1 | | −21.0° | −11.5° | 68.0% | −21.3° | −10.7° |
| Milk stage | 100% | 5 | 67.5% | −23.5 | − 7.4 | 64.5 | −19.4 | −11.2 |
| Milk stage | 100 | 10 | 70.5 | −20.1 | − 9.6 | 74.2 | −18.7 | − 9.0 |
| Milk stage | 100 | 11 | 69.7 | −15.6 | − 7.9 | | | |
| Milk stage | 100 | 12 | 69.3 | −19.0 | −10.1 | 67.8 | −20.3 | −11.8 |
| Milk stage | 32 | 5 | 65.9 | −22.3 | −11.7 | 64.2 | −21.3 | −10.4 |
| Milk stage | 32 | 10 | 62.1 | −24.1 | −13.8 | 61.3 | −27.4 | −17.6 |
| Milk stage | 32 | 11 | 65.5 | −18.7 | − 9.3 | 65.0 | −17.8 | − 9.0 |
| Milk stage | 32 | 12 | 67.5 | −17.1 | − 8.1 | 68.4 | −20.3 | − 9.1 |
| Dough stage | | 1 | 65.7 | −17.8 | − 8.7 | 64.6 | −17.8 | − 9.5 |
| Dough stage | 100 | 5 | 65.2 | −20.1 | − 9.6 | 65.7 | −16.8 | − 8.4 |
| Dough stage | 100 | 10 | 68.3 | −19.7 | − 9.1 | 65.1 | −20.1 | − 9.8 |
| Dough stage | 100 | 11 | 69.4 | −19.9 | −10.4 | 66.7 | −17.9 | − 9.7 |
| Dough stage | 100 | 12 | 60.3 | −15.0 | − 6.8 | | −15.5 | − 7.5 |
| Dough stage | 32 | 5 | 64.9 | −19.7 | −10.4 | 65.1 | −18.8 | −10.7 |
| Dough stage | 32 | 10 | 64.3 | −17.8 | − 8.2 | 59.6 | −19.8 | −10.9 |
| Dough stage | 32 | 11 | | −16.9 | − 8.7 | 58.8 | −21.0 | −10.6 |
| Dough stage | 32 | 12 | 62.1 | −20.1 | −10.0 | 58.4 | −15.0 | − 7.1 |

**Table 10.—Undercooling and freezing points and per cent water of pupae at 100 and 32 per cent humidities and 18.9 degrees from larvae reared on dough stage and milk stage corn, prepupae in moist soil.**

| Food.—Corn in: | Humidity | Age (days) | Male | | | Female | | |
|---|---|---|---|---|---|---|---|---|
| | | | Water | Undercooling Temp. | Freezing Temp. | Water | Undercooling Temp. | Freezing Temp. |
| Milk stage | | 1 | 69.1% | −17.6° | − 9.1° | 68.5% | −17.4° | −11.4° |
| Milk stage | 100% | 4 | 68.2 | −16.6 | − 8.2 | 67.9 | −15.3 | − 7.2 |
| Milk stage | 100 | 17 | | | | 70.0 | −18.7 | − 9.4 |
| Milk stage | 100 | 21 | 71.7 | −19.8 | −11.8 | 67.6 | −19.9 | − 9.9 |
| Milk stage | 100 | 27 | 71.2 | −18.0 | − 9.4 | 70.8 | −16.8 | − 7.8 |
| Milk stage | 32 | 17 | | | | 64.4 | −17.6 | −10.4 |
| Dough stage | | 1 | 66.8 | −17.4 | − 8.0 | 63.2 | −17.3 | − 8.5 |
| Dough stage | 100 | 4 | 66.2 | −14.8 | − 9.1 | 64.5 | −16.5 | − 8.9 |
| Dough stage | 100 | 15 | 65.1 | −18.2 | − 8.7 | 64.3 | −18.2 | − 8.7 |

degrees, it is of economic interest to determine what effect water content has on the cold hardiness of non-diapausing pupae and to find the relative ability of pupae which undergo diapause and those which do not to harden or develop ability to survive low temperatures. Such information should be of value in interpreting what takes place under field conditions.

It was assumed from the work of Robinson (1927 a), Payne (1926), and Saccharov (1930), that freezing point and freezable water determinations were reliable indices of winter hardiness, and they were accordingly used. The results of freezing point and undercooling point determinations for prepupae and pupae at regular intervals during the prepupal and pupal periods under varying conditions of temperature and humidity with moisture determinations for the same samples are given in tables 8, 9, and 10. Freezable water determinations were made on similar samples and results are given in tables 11, 12, and 13. Undercooling and freezing points are based on averages of samples of five insects each. Freezable water results are based on averages of duplicate samples of three or four insects each. Freezable water averages given in tables are not weighted.

Undercooling and freezing points were higher for prepupae than for pupae. At 30 degrees for one day old prepupae in

**Table 11.—Percentage of water unfreezable at −19.3 degrees, ratio of unfreezable water to dry weight, and per cent total water for pupae at 100 and 32 per cent humidities and 30 degrees from larvae reared at 30 degrees, prepupae in moist soil.**

| Food.—Corn in: | Humidity | Age (days) | Male | | | Female | | |
|---|---|---|---|---|---|---|---|---|
| | | | Water | Unfreezable water | Ratio unfreezable water to dry wt. | Water | Unfreezable water | Ratio unfreezable water to dry wt. |
| Milk stage | | 1 | 66.9% | 17.2% | .35 | 65.4% | 22.2% | .43 |
| Milk stage | 100% | 4 | 68.7 | 13.9 | .30 | 67.5 | 12.3 | .25 |
| Milk stage | 100 | 7 | 70.7 | 19.4 | .47 | 67.3 | 16.7 | .34 |
| Milk stage | 100 | 8 | 70.6 | 17.7 | .47 | 70.0 | 16.3 | .38 |
| Milk stage | 100 | 9 | 71.6 | 14.1 | .36 | 71.1 | 16.0 | .41 |
| Milk stage | 32 | 4 | 65.9 | 16.9 | .35 | 65.3 | 14.4 | .28 |
| Milk stage | 32 | 7 | 65.4 | 18.3 | .35 | 61.1 | 14.6 | .23 |
| Milk stage | 32 | 8 | 61.9 | 18.4 | .29 | 61.6 | 18.2 | .30 |
| Milk stage | 32 | 9 | 61.8 | 19.8 | .32 | | | |
| Dough stage | | 1 | 67.5 | 13.8 | .28 | 64.9 | 12.9 | .24 |
| Dough stage | 100 | 4 | 65.4 | 15.5 | .29 | 65.9 | 12.6 | .24 |
| Dough stage | 100 | 7 | 69.7 | 15.5 | .35 | 67.3 | 16.8 | .34 |
| Dough stage | 100 | 8 | 69.0 | 12.1 | .17 | 68.1 | 15.1 | .32 |
| Dough stage | 100 | 9 | 68.1 | 12.4 | .26 | 67.0 | 12.7 | .26 |
| Dough stage | 32 | 4 | 65.9 | 17.9 | .32 | 60.5 | 14.7 | .23 |
| Dough stage | 32 | 7 | 60.8 | 17.8 | .28 | 61.6 | 19.2 | .31 |
| Dough stage | 32 | 8 | 62.5 | 19.3 | .32 | 60.3 | 16.0 | .24 |
| Dough stage | 32 | 9 | 62.4 | | .19 | 59.4 | 18.8 | .27 |

Table 12.—Per cent of water unfreezable at −19.3 degrees, ratio of unfreezable water to dry weight and per cent total water for pupae at 100 and 32 per cent humidities and 24.4 degrees from larvae reared at 24.4 degrees, prepupae in moist soil.

| | | | Male | | | Female | | |
|---|---|---|---|---|---|---|---|---|
| Food.—Corn in: | Humidity | Age (days) | Water | Unfreezable water | Ratio unfreezable water to dry wt. | Water | Unfreezable water | Ratio unfreezable water to dry wt. |
| Milk stage | | 1 | 68.0% | 17.9% | .38 | 68.0% | 18.0% | .38 |
| Milk stage | 100% | 5 | 67.5 | 20.4 | .42 | 66.0 | 16.0 | .31 |
| Milk stage | 100 | 10 | 71.6 | 15.6 | .40 | 71.1 | 17.9 | .44 |
| Milk stage | 100 | 11 | 70.4 | 13.7 | .33 | 69.9 | 16.0 | .37 |
| Milk stage | 100 | 12 | 69.8 | 15.3 | .35 | 68.1 | 15.2 | .32 |
| Milk stage | 32 | 5 | 66.7 | 13.6 | .27 | 66.5 | 17.9 | .35 |
| Milk stage | 32 | 10 | 65.3 | 20.3 | .38 | 64.3 | 23.9 | .47 |
| Milk stage | 32 | 11 | 65.4 | 15.4 | .29 | 62.9 | 17.8 | .30 |
| Milk stage | 32 | 12 | 62.4 | 19.9 | .33 | 61.4 | 20.0 | .31 |
| Dough stage | | 1 | 66.8 | 14.1 | .29 | 62.5 | 13.3 | .22 |
| Dough stage | 100 | 5 | 63.1 | 14.0 | .26 | 63.3 | 15.6 | .27 |
| Dough stage | 100 | 10 | 67.3 | 13.6 | .23 | 66.7 | 12.9 | .28 |
| Dough stage | 100 | 11 | 67.7 | 17.4 | .35 | 62.4 | 17.4 | .33 |
| Dough stage | 100 | 12 | 67.6 | 16.2 | .34 | 68.5 | 13.1 | .30 |
| Dough stage | 32 | 5 | 65.8 | 16.5 | .33 | 63.6 | 14.6 | .25 |
| Dough stage | 32 | 10 | 63.2 | 13.4 | .22 | 62.4 | 19.1 | .33 |
| Dough stage | 32 | 11 | 63.9 | 13.3 | .24 | 59.5 | 17.2 | .25 |
| Dough stage | 32 | 12 | 60.8 | 13.9 | .23 | 59.5 | 13.5 | .21 |

moist soil from larvae reared on milk stage corn, the following figures were obtained: undercooling point −13.9 degrees freezing point −5.2 degrees; for two day old prepupae −9.9 degrees and −5.2 degrees; for comparable samples of prepupae from larvae reared on dough stage corn, one day old prepupae had an undercooling point of −12.8 degrees and a freezing point of −6.0 degrees; two day old prepupae, −9.7 degrees and −5.3 degrees. In prepupal samples from larvae reared at 24.4 degrees on milk stage corn, prepupae one day old had an undercooling point of −13.9 degrees and a freezing point of −8.8 degrees; three day old prepupae −12.1 degrees and −5.0 degrees. In similar samples from larvae reared on dough stage corn the temperatures for one day old prepupae were: undercooling point −8.7 degrees, freezing point −4.6 degrees; for three day prepupae −8.9 degrees and −5.0 degrees. For prepupae at 18.9 degrees, from larvae reared on milk stage corn the undercooling points were: one day, −13.7 degrees, three day.

Table 13.—Per cent of water unfreezable at −19.3 degrees, ratio of unfreezable water to dry weight and per cent total water for pupae at 100 and 32 per cent humidities reared from larvae at 18.9 degrees on dough stage and milk stage corn, prepupae in moist soil (older pupae not in diapause, younger undetermined).

| | | | Male | | | Female | | |
|---|---|---|---|---|---|---|---|---|
| Food.—Corn in: | Humidity | Age (days) | Water | Unfreezable water | Ratio unfreezable water to dry wt. | Water | Unfreezable water | Ratio unfreezable water to dry wt. |
| Milk stage | | 1 | 70.6% | 15.5% | .38 | 68.7% | 15.7% | .34 |
| Milk stage | 100% | 4 | 68.7 | 12.9 | .28 | 66.6 | 13.3 | .30 |
| Milk stage | 100 | 17 | 70.6 | 14.2 | .34 | 67.4 | 15.2 | .31 |
| Milk stage | 100 | 22 | 69.7 | 12.9 | .31 | 69.7 | 13.2 | .30 |
| Milk stage | 100 | 27 | 72.9 | 13.8 | .37 | 70.9 | 13.2 | .33 |
| Milk stage | 32 | 4 | 68.3 | 13.8 | .29 | 67.4 | 15.2 | .31 |
| Milk stage | 32 | 17 | 66.5 | 17.4 | .35 | 65.0 | 15.1 | .29 |
| Dough stage | | 1 | 65.3 | 12.7 | .24 | 64.9 | 13.7 | .24 |
| Dough stage | 100 | 4 | 68.0 | 16.1 | .34 | 63.2 | 15.3 | .27 |
| Dough stage | 100 | 15 | 66.0 | 15.5 | .30 | 65.1 | 19.4 | .37 |
| Dough stage | 100 | 24 | 68.0 | 13.6 | .29 | 66.5 | 14.6 | .31 |

−13.3 degrees, six day, −11.8 degrees; freezing points: one day, −7.5 degrees, three day, −8.2 degrees, six day, −5.7 degrees. For similar samples reared on dough stage corn undercooling points were: on day prepupae −8.9 degrees, 3 day, −10.1 degrees, six day, −9.2 degrees; freezing points were: one day, −4.5 degrees, three day, −5.8 degrees, six day, −5.5 degrees.

In tables 11 to 13, both the percentage of water unfreezable at −19.3 degrees and the ratio of unfreezable water to dry weight are given. The first indicates the actual amount of water unfreezable while the dry weight ratio probably indicates either the efficiency of the water-holding capacity of the hydrophilic colloids or their abundance.

Pupae undergoing diapause from larvae reared at 18.9 degrees on dough stage and milk stage corn had undercooling and freezing points in the same order as those for active pupae. Various samples of unhardened pupae in diapause, 15 to 27 days of age, had undercooling points of −16.4, −20.0, −12.6, and −16.4 degrees; freezing points of −7.9, −9.2, −8.0, and −10.2 degrees. The percentage of water unfreezable was also about the same as for pupae not in diapause. Five samples of pupae between 15 and 27 days of age had 15.1 to 15.4 per cent of water unfreezable and ratios of dry weight to unfreezable water of .28 to .31. Two other samples had 11.6 and 13.5 per cent unfreezable water, and dry weight ratios of .22 and .27.

Preliminary attempts to "cold harden" pupae in and not in, diapause by continuous low temperatures of 5 to −2 degrees were unsuccessful. One group of pupae not in diapause from larvae reared on dough stage corn at 30 degrees, after being in the refrigerator 40 days, had 17.9 per cent water unfreezable, had an average undercooling point of −21.0 degrees, and a freezing point of −11.1 degrees. A similar group of seven pupae after being in the refrigerator 56 days had an average undercooling point of −15.1 degrees and a freezing point of −8.4 degrees. Pupae in diapause (from larvae reared on dough stage corn) in the refrigerator 39 days had an undercooling point of −18.6 degrees and a freezing point of −10.7 degrees. Alternating the pupae between the refrigerator (five days) and the 24.4 degree incubator (two days) gave more encouraging results. Pupae in diapause (from dough stage corn) after three five-day periods in the refrigerator had an average undercooling point of −22.2 degrees and freezing point of −14.1 degrees. Unfreezable water for similar samples of pupae was 18.8, 20.2, 17.1, 17.7, and 18.0 per cent. Pupae not in diapause from larvae reared on dough stage corn at 30 degrees were placed in the refrigerator for 35 days, then alternated between the refrigerator and the 24.4 degree incubator for 16 days, after which they had an average undercooling point of −18.8 degrees and a freezing point of −8.9 degrees; unfreezable water in four samples of these pupae was 14.2, 16.7, 15.9, and 15.0 per cent.

These observations indicate that pupae in diapause cold harden and that the process is accelerated by alternating low and warm temperatures. It is doubtful if pupae not in diapause can be hardened; when warm temperatures occur, the pupae resume development with no hardening tendency. The extent to which diapausing pupae will harden was not determined. One observation on a group of pupae carried over the winter of 1938–39 is interesting. After 10 months in the refrigerator, only pupae in diapause remained, and although the live and dead insects could not be immediately separated with certainty, undercooling points of healthy-appearing individuals varied between −15 and −20 degrees, freezing points between −8 and −12 degrees. The remaining pupae were held at 18.9 degrees for several days and then at 24.4 degrees for a week. After this treatment, undercooling points of eight living pupae varied between −38 and −45 degrees, and freezing points between −28 and −35 degrees, comparable to the values obtained by Payne (1926) for hardy oak borer larvae.

The water content of the above pupae varied from 61 to 68 per cent and no relation of water content to freezing points or freezable water was observed.

The results of attempts to harden pupae are only preliminary but indicate an interesting field for investigation.

No attempts were made during the freezing point observations to determine the temperature at which death took place; however, it was noticed that pre-

pupae and older pupae often recovered quickly when they were warmed up whereas young pupae seemed more susceptible to freezing temperature.

DISCUSSION.—Humidity exerted considerable influence on the loss of weight of prepupae, and this loss was accurately measured since the same individuals could be weighed at regular intervals during their life. As humidity was reduced from 100 to per cent zero, the rate of loss of weight was at first rapid, then gradually decreased at the lower humidities (Table 3). At 75 per cent humidity 9 to 19 per cent more weight was lost than at 100 per cent. Reduction to 55 per cent humidity caused only 2 to 6 per cent increase in weight loss. When humidity was decreased to 32 per cent there was a further 3 to 5 per cent additional weight loss but there were no significant differences in weight loss at 32 per cent and zero humidities.

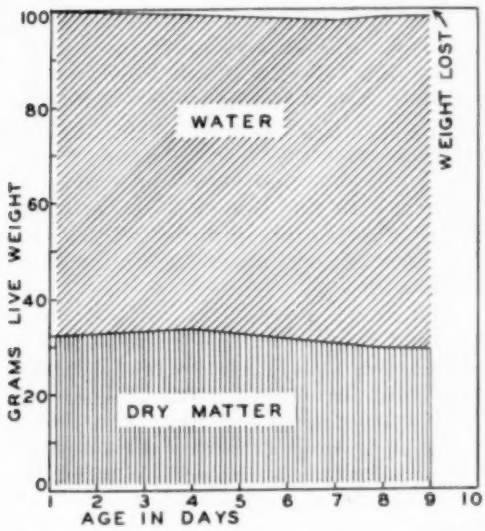


FIG. 6.—Change in dry matter, water, and total weight during the pupal period at 30 degrees and 100 per cent humidity for male pupae reared on milk stage corn at 30 degrees, prepupae in moist soil.

Moisture analyses of pupae kept in similar conditions were made to determine how much of the weight loss of pupae under various conditions of humidity could be attributed to loss of water and how much to loss of dry matter. Based on the results in table 5, calculations for the loss of live weight, water, and dry matter of pupae reared on milk stage corn at 30 degrees and humidities of 100 and 32 per cent are presented in graphic form in figures 6 and 7. The following procedure was followed: at 100 per cent humidity 100 grams of day-old male pupae with 68 per cent moisture contained 68 grams of water and 32 grams of dry matter. At nine days they had

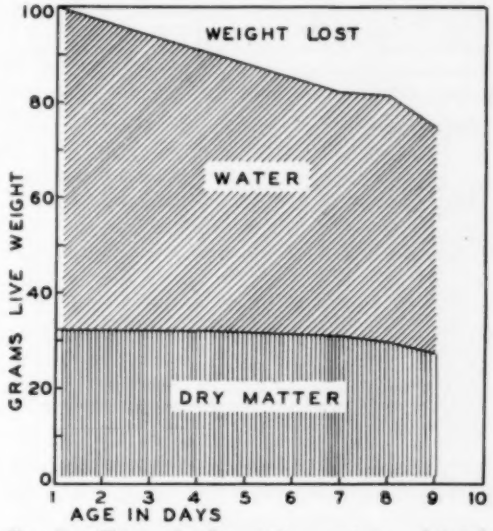


FIG. 7.—Change in dry matter, water, and total weight during the pupal period at 30 degrees and 32 per cent humidity for male pupae reared on milk stage corn at 30 degrees, prepupae in moist soil.

lost 1.4 per cent of their weight and contained 70.5 per cent water so that there remained 98.6 grams of live weight of which 69.5 grams was water and 29.1 grams was dry matter, an actual increase of 1.5 grams of water and a decrease of 2.9 grams of dry weight. At 32 per cent humidity there was a 25 per cent loss of live weight between the first and ninth days of life, which on the basis of 100 grams of live weight consisted of a decrease of 20.5 grams of water and 4.7 grams of dry matter (Fig. 7).

Calculations of the relative amounts of water gained or lost and of dry matter lost for 100 grams of live weight based on the rates in tables 5 and 6 are given in table 14. These weight changes are based on a water content of 68 per cent for male pupae and 67 per cent for female pupae from larvae reared on milk stage corn; 65 per cent for male pupae and 64 per cent water for female pupae from larvae reared on dough stage corn. These are the higher limits of water content for pupae reared under these respective con-

ditions. If a lower percentage of water is used for the day-old pupae with a consequent higher percentage of dry matter at that time, the calculated weight of dry matter lost during the period will be slightly greater; consequently the loss of dry weight in table 14 is the minimum to

**Table 14.—The effect of humidity during the pupal period on the grams of water lost or gained and grams of dry weight lost based on 100 grams of day-old pupa from data given in tables 5 and 6.**

| Food.—Corn in: | Temp. | Humidity | Sex | Water Lost | Dry Matter Lost |
|---|---|---|---|---|---|
| | | | | grams | grams |
| Milk stage | 30.0° | 100 | F | + 1.0 | 2.1 |
| Milk stage | 30.0 | 32 | F | −24.5 | 4.6 |
| Milk stage | 24.4 | 100 | M* | + 1.0 | 3.1 |
| Milk stage | 24.4 | 100 | F | + 0.3 | 4.1 |
| Milk stage | 24.4 | 32 | M | −19.0 | 4.1 |
| Milk stage | 24.4 | 32 | F | −19.5 | 4.3 |
| Dough stage | 30.0 | 100 | M† | − 2.2 | 4.9 |
| Dough stage | 30.0 | 100 | F | + 4.1 | 5.9 |
| Dough stage | 30.0 | 32 | F | −15.4 | 4.3 |
| Dough stage | 24.4 | 100 | M | + 1.8 | 4.8 |
| Dough stage | 24.4 | 100 | F | − 0.1 | 2.8 |
| Dough stage | 24.4 | 32 | M | −19.3 | 3.2 |
| Dough stage | 24.4 | 32 | F | −16.5 | 5.9 |

* 8-day pupae. † 11-day pupae.

be expected. It is evident from examination of table 14 that the loss of weight during the pupal period as caused by reduction in humidity can be attributed to variation of water content, the reduction of dry matter being at a stable rate. Increase in water content is partly attributed to water resulting from oxidation of fat and carbohydrate (glycogen). Only when pupae are submerged in water is any appreciable amount absorbed.

Previous results (Ditman, 1938; Ditman and Weiland, 1938) indicate that .0015 to .002 gram of fat and approximately 4 to 5 grams of glycogen are utilized during the pupal period for each 100 grams weight of pupa. The losses of weight shown in table 14 would account for this. Just what happens to the protein is not known but it is hoped that this will be investigated later. However, there could be some protein utilized with little change in dry matter as the nitrogenous end products are not excreted and would tend to maintain dry weight.

The effect of cool temperature (about 18.9 degrees) during the larval period in causing diapause in the pupal stage is of particular interest. It explains the occurrence of occasional diapausing pupae during the summer and the preponderance of pupae with tendency to enter diapause found during September under field conditions. When cool periods occur during the summer or when larvae may be feeding in cool places, diapausing pupae should and do occur. Temperatures inside the husk of corn ears are usually two to five degrees lower than atmospheric temperatures and when mean daily temperatures approach 20 degrees pupae in diapause should occur. In late August or early September in the region of Washington, D. C., daily mean temperatures usually drop rapidly and account for the pupae in diapause found at this season.

Water content of the insect apparently exerts no influence on diapause since pupae in diapause vary in water content in the same order as do the others. There seems to be no inherited periodicity as to diapause as pupae reared at 30 and 24.4 degrees from larvae collected in the field at all times during summer and fall of the year never exhibit diapause, whereas those reared at 18.9 degrees collected in the field during the same period do. The age of corn used as larval food may play a minor role in causing diapause in pupae, as the results in table 7 indicated, but the difference is of doubtful validity. In small groups (16) of pupae from larvae reared on milk stage corn as many as 60 per cent of the pupae exhibited diapause. There is little question as to the primary effect of cool temperature during the larval period in causing diapause among resulting pupae.

Undercooling and freezing point determinations showed no constant relationship to sex, temperature, or dehydration. In some instances (Tables 8, 9, and 10) pupae appeared to be more resistant to cold as they became older, but at other times the reverse was true. The variation among individuals was such that significance is not given to any differences observed. As a group, the undercooling and freezing temperatures indicate that even non-winterhardy pupae (not in diapause) can survive subzero temperatures for at least short periods of time. As a matter of comparison, nonhardened earworm pupae had undercooling and freezing points of the same order as pupae of the summer generation of *Diatraea crambidoides* (Grote), an insect which spends the winter in the larval stage and is normally very cold hardy. Mexican bean beetle adults of the first summer generation had undercooling

(−10 degrees) and freezing (−5 degrees) points of about one-half the values found for ear worm pupae. Non-hardened pupae in diapause had undercooling and freezing points of the same order as active pupae when kept under similar conditions and not previously exposed to low temperatures. Attempts to harden pupae by continuous low temperature and by alternating low and mild temperatures indicate that the latter are more effective, probably necessary. It is doubtful if active pupae can be cold hardened at all, particularly since alternating temperatures appear to be required. When pupae not in diapause were exposed to mild temperature after a cold shock, they resumed normal development whereas dormant pupae responded by developing resistance to cold. The degree to which pupae in diapause will harden and the most effective temperatures for cold hardening have yet to be determined, but preliminary observations indicate that such pupae do harden and may be as winter hardy as many of our native insects. If this is true, it will be only during the occasional winter in eastern Maryland that dormant pupae will be killed directly by cold. It is probable that winter mortality is caused by the physical action of cold on the soil in breaking up pupal burrows, as pointed out recently by Dicke (1939). When the burrow is once broken up and soil packed closely around the pupa, it cannot survive.

## CONCLUSIONS

1. Larvae attain greater size when reared at 24.4 degrees than at 30 degrees. Pupae are larger when the prepupal period is spent in relatively wet soil than in dry soil.

2. Death of prepupae results from dehydration in dry soil (1 to 2 per cent moisture) at 18.9 degrees or below; mortality is high among prepupae in wet soil (18 to 25 per cent moisture) at 13.3 degrees.

3. Loss of weight during the pupal period varies inversely as the humidities at which the pupae have been stored; soil moisture has a similar effect. At constant low humidity there is a greater weight loss during the entire pupal stage at cool incubator temperatures than at warm, a result of longer exposure. Pupae in diapause lose weight less rapidly at low humidity than pupae not in diapause.

4. Differences in loss of weight at various humidities appear to be due entirely to variations in loss of water rather than of dry weight.

5. Diapause during the pupal period is caused by low temperatures during the larval period. Larvae reared at 18.9 degrees produce pupae, some groups of which diapause to the extent of 50 per cent. This explains the occasional occurrence of pupae undergoing diapause during the summer after cool weather and the preponderance of pupae with tendency to enter diapause which are always to be found in early fall.

6. Undercooling and freezing points and bound water determinations indicate that even corn earworm pupae not in diapause can stand subzero temperatures for at least short periods. Preliminary attempts to cold harden pupae indicate that alternating low and high temperatures are necessary and that only individuals in diapause harden. Pupae not undergoing diapause resume their normal development during periods of warmth.—11-16-39.

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# Methyl Bromide Fumigation for Japanese Beetle Control

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During the period of adult activity of Japanese beetles (*Papillia japonica*, Newm.) in the area under quarantine because of this insect, fresh fruits and vegetables for shipment to points outside the area must be handled in such a manner as to be freed from infestation. Soon after Mackie (1937) showed that methyl bromide could be used for the treatment of certain fruits, vegetables and living plants in insecticidal concentrations without injury to the commodity, work was begun in the Bureau of Entomology and Plant Quarantine on the development of a method for the treatment of commodities, in vaults or in refrigerator cars, for the destruction of the adult Japanese beetle. The project was carried on in 1936 and 1937 by Johnson and Bulger, in 1938 by Donohoe, Johnson, and Bulger, and in 1939 by Donohoe. The present paper describes the development of the method by which successful fumigation of fruits and vegetables is being accomplished, both in especially constructed fumigation vaults and in refrigerator cars.

It is essential that any fumigation method for quarantine purposes, if properly supervised and applied within predetermined limits, shall give assurance of complete mortality of the insect involved. At the same time, because such treatments deal frequently with highly perishable, easily injured living commodities, there must be an adequate margin of safety between the schedule necessary to insure complete mortality and that likely to cause commodity injury. Time is also a factor, as delay in the usual processes of preparing the commodities for the market may result in financial loss to the shippers because of deterioration or of varying market demands.

In view of these considerations, no attempt has been made to follow the usual procedure in investigating the insecticidal value of a chemical, such as to determine or to plot the theoretical time-temperature-dosage relationships. Rather, the development of methyl bromide fumigation for the Japanese beetle has been based on a fixed 2-hour exposure period and the determination from this point of dosages, based on existing temperatures, which, in repeated trials, give assurance of complete mortality. At each prospective schedule the practice has been to obtain multiple records to determine the approximate minimum effective temperature and to prove the dependability of the schedule above this temperature. In the sense used, the minimum effective temperature is that at which, for the particular dosage used, complete mortality of all beetles, in both vault space and load, is consistently obtained.

For practical purposes two zones of insect occurrence may be distinguished within an enclosure containing a commodity to be fumigated, the space occupied by the material or commodity being fumigated and the remainder of the space within the enclosure. The writers suggest the term "vault space" for this unoccupied portion of a fumigation enclosure to distinguish it from the portion of the space occupied by the load.

Within the vault space, distribution of the fumigant is relatively unimpeded. Within the load, on the other hand, distribution may be dependent upon the type of commodity, the method of packing, and the ratio of load to vault space; it may be hindered or prevented by the difficulty of mechanical penetration and diffusion, by absorption and adsorption by both commodity and package, and by the presence on the commodity of moisture and perhaps of chemicals applied before packaging for the purpose of preservation or protection during production or marketing. Except for the effect of surface-applied chemicals, which has been little explored, none of these factors except mechanical penetration and diffusion have been found to affect materially the activity of methyl bromide.

All the adult beetles used in the fumigations were hand-collected and, with few exceptions, were used on the day of collection. When this was not possible, they were held in well-ventilated cages with an abundance of food. In preparation for use, the weak beetles on and near the cage floor were discarded.

VAULT FUMIGATIONS OF JAPANESE BEETLE ADULTS.—Both for direct application to the problem of freeing fresh fruits and vegetables from adult Japanese beetles and as supporting evidence during the development of fumigation in refrigerator cars, much attention has been centered on vault fumigations. The fumigation vaults were portable boxes 100, 50, and 33 cubic feet in capacity, lined with galvanized iron and provided with an evaporating pan hung near the ceiling at one end of the box. Each vault was equipped with an electric fan for thoroughly mixing the fumigant with the air in the chamber at the start of the exposure period. The fan was operated for 5 to 20 minutes, usually 5, after the dosage had been poured into the evaporating pan through a funnel at the top of the box. A pan having an area of 60 square inches or more for every 100 cubic feet of enclosed space has been determined to be advisable for rapid evaporation of methyl bromide.

The beetles were caged in cork-stoppered 1 by 6-inch cylindrical screen wire containers. These were distributed at the top, on the floor, and frequently near the center, of the vault, and where a load was involved they were buried at various depths within the commodity. In general, the cages were removed from the vault space within 15 minutes after ventilation was begun, and from the load on the succeeding day to allow for the post-fumigation effect, which is important in fumigations involving any but the most loosely packed commodities.

If any beetles were alive after removal from the test locations, they were emptied into well-ventilated 4 by 8-inch cylindrical cages, fed sassafras or other palatable leaves, and held for mortality observations. Within a day after fumigation they were counted, the dead beetles removed, and the live beetles held for subsequent inspections. Frequently the dead beetles likewise were held for several days and given successive examinations, but there was never any recovery of beetles originally recorded as dead. Moreover, no beetle so affected by methyl bromide at the time of removal as to be unable to crawl ever recovered later.

The data obtained from the vault fumigation of adult beetles are shown in table 1. In the earlier work all effort was concentrated on testing the schedule of 2 pounds per 1,000 cubic feet for 2 hours under various conditions of amount and type of load. This accounts in part for the numerous records well above the minimum effective temperature.

The load temperature was not taken for most of the tests. In the nine records obtained, it was always somewhat lower than the temperature of the vault.

It is anticipated that, for the next several years at least, fumigation of produce will be carried out largely in refrigerator cars. The average volume of space within a refrigerator car is 2,500 cubic feet. Dependent upon the commodity and type of package, the amount of load in such a car is more or less constant. For example, in a loaded car the volume of produce per 100 cubic feet of space is approximately 7 barrels or 12 hundred-pound bags of potatoes, 20 bushels of tomatoes or cucumbers, 40 twelve-quart climax baskets, or 27 thirty-pound lugs of tomatoes. The ratio of occupied to enclosed volume of space in a loaded car, if given a unit value of one, affords a suitable basis for comparing fumigations involving a less fully loaded fumigable space. In the tables "load ratio" indicates the approximate fraction of the volume within the fumigation vault occupied by load in comparison with the volume occupied by a similar load in a fully loaded refrigerator car. Because of the unoccupied bunker spaces in cars, this basis for comparison is not an exact one, but with rapid evaporation and distribution of the fumigant to the entire vault space in car fumigations, arrangement of load does not appear to be an important factor, or one that lessens the value of the "load ratio" for purposes of comparison.

In table 1 the mortality was complete in all tests except as noted. In all tables "days held" represents the maximum interval between fumigation and the examination giving the percentage mortality indicated.

As is apparent from the tables, methyl bromide penetrates readily into packages of produce and apparently is not absorbed or adsorbed by any of the products in amounts sufficient to reduce its effectiveness. There was no evidence of reduced effectiveness with increased load ratio, or vice versa. This does not mean that

**Table 1.—Vault fumigations of Japanese beetle adults with methyl bromide.**

| Temperature Range, °F. | | Load | Load Ratio | No. of Beetles Used | | Days Held | Control Mortality, Per Cent |
|---|---|---|---|---|---|---|---|
| Vault | Load | | | In vault space | In load | | |
| **2 Pounds per 1,000 Cubic Feet for 2 Hours** | | | | | | | |
| 65–66 | 64–67 | Potatoes | 1/2 | 1,113 | 3,162 | 2 & 4 | 22.3 |
| 66–68 | 64–67 | Potatoes | 1/2 | 1,038 | 3,524 | 3 & 4 | 22.3 |
| 70–70 | 67–67 | Potatoes | 5/6 | — | 1,385 | 1 | 9.9 |
| 70–70 | 67–67 | Potatoes | 1/3 | 219 | 963 | 1 | 9.9 |
| 70–72 | | Potatoes | 4/5 | — | 3,012 | 1 | 2.1 |
| 72–74 | | Gladiolus (blooms) | 1/20 | 4,336 | — | 1 | 1.5 |
| 74–74 | | Potatoes | 1/6 | — | 383 | 2 | 4.3 |
| 74–74 | | Beans and cabbage | 5/8 | — | 773 | 1 | 0.9 |
| 74–77 | | Sweet corn | 1/12 | — | 1,556 | 1 | 1.5 |
| 75–82 | | Cabbage | 3/4 | 260 | 759 | 1 | 15.6 |
| 76–76 | | Potatoes and snap beans | 1/4 | -- | 392 | 2 | 0.0 |
| 76–79 | | Potatoes | 2/5 | 2,715 | — | 1 | 0.6 |
| 77–77 | | Potatoes | 4/5 | — | 802 | 1 | 0.0 |
| 78–83 | | Cabbage | 3/4 | 508 | 999 | 1 | 25.5 |
| 79–80 | | Onions | 1/4 | — | 699 | 1 | 1.1 |
| 79– | | Snap beans and cabbage | 3/4 | — | 902 | 1 | 0.9 |
| 80– | | Cucumbers and tomatoes | 1/4 | — | 573 | 1 | 15.0 |
| 80–83 | | Mixed produce | 1/3 | — | 2,468 | 1 | 3.3 |
| 82– | | Cucumbers and tomatoes | 1/7 | — | 1,232 | 1 | No record |
| 82–84 | | Mixed produce | 1 | — | 1,370 | 1 | 26.2 |
| 84– | | Cucumbers and tomatoes | 1/7 | — | 749 | 1 | 15.0 |
| 84–87 | | Mixed produce | 2/3 | 563 | 1,566 | 1 | 0.8 |
| 87–88 | | Sweet corn | 3/4 | 431 | 817 | 1 | 3.9 |
| 88–91 | | Cantaloup | 1/4 | — | 517 | 1 | 11.8 |
| 89–90 | | Cucumbers and cabbage | 1/12 | — | 200 | 1 | 5.0 |
| 90– | | Cabbage | 1/6 | — | 759 | 1 | 10.6 |
| Total | | | | 11,183 | 29,562 | — | — |
| **1 Pound per 1,000 Cubic Feet for 2 Hours** | | | | | | | |
| 74–74 | | Potatoes | 3/7 | 2,576 | 3,352* | 1 & 3 | 0.6 at 1 day |
| 76– | | Potatoes | 6/7 | 2,515 | 4,106 | 1 & 7 | 4.0 |
| 79–81 | | Potatoes | 4/7 | 3,661 | 3,097 | 1 & 4 | No record |
| 80–81 | | Potatoes | 4/7 | 1,172 | 3,543 | 1 | 7.0 |
| 82–84 | 79–79 | Potatoes | 6/7 | 1,701 | 2,060 | 1 | 4.0 |
| 82–84 | | Potatoes | 2/7 | 1,411 | 2,087 | 1 | 2.7 |
| 83– | | Potatoes | 1/2 | 2,868 | 1,207 | 1 | 2.7 |
| 84–84 | | Potatoes | 2/7 | 1,766 | 2,433 | 1 | No record |
| 84–87 | | None | — | 1,902 | — | 1 | 0.9 |
| 86–86 | | Potatoes | 2/7 | 2,963 | 2,996 | 1 | 2.7 |
| 86–91 | | None | — | 1,638 | — | 1 | 2.7 |
| 87–89† | | Potatoes | 2/7 | 3,224 | 2,549 | 1 | 2.7 |
| Total | | | | 27,397 | 27,430 | — | — |
| **0.75 Pound per 1,000 Cubic Feet for 2 Hours** | | | | | | | |
| 77– | | None | | 1,060 | — | 1 | 1.2 |
| 83–84 | 75–77 | Cucumbers | 1/6 | — | 1,495 | 5 | 48.1 |
| 84–84 | 80–80 | Potatoes | 4/7 | 1,356 | 2,240 | 1 & 2 | 4.0 |
| 84–86 | 80–80 | Potatoes | 4/7 | 1,108 | 1,444 | 1 | 18.2 |
| 84–87 | 80–80 | Potatoes | 1/2 | 990 | 1,576 | 1 | 18.2 |
| 86– | | None | | 1,192 | — | 1 | 0.9 |
| Total | | | | 5,706 | 6,755 | — | — |

* Mortality 90.7 per cent at the end of 3 days.
† Exposure period 1½ hours only.

commodities do not absorb methyl bromide, for it is well known that such absorption occurs. Rather, it appears that absorption and adsorption by fresh produce is so slight that it is not a factor in the development of commercially applicable dosages.

The data presented in the tables, involving a total or more than 108,000 beetles, indicate that complete mortality of Japanese beetle adults, both in vault space and load, can be obtained by methyl bromide fumigation at suitable temperatures within a 2-hour exposure period with

dosages of 2.0, 1.0 and 0.75 pounds per 1,000 cubic feet.

REFRIGERATOR CAR FUMIGATIONS.—Experimental fumigations of refrigerator cars were first undertaken in 1937. The development of a commercially successful car treatment was accomplished by the beginning of the 1938 season, under quarantine against adult beetles, and was immediately put into use. The steps leading up to this treatment, as well as subsequent studies, are discussed below.

From the standpoint of quarantine enforcement it is important to obtain complete kill of beetles in a car in the interval between fumigation and movement of the car to any transit inspection point outside the regulated area. Since this interval is seldom longer than four or five days, and since methyl bromide acts slowly, complete mortality within this time limit may require dosages in excess of those that eventually would be lethal. Even though experimental evidence might show that mortality at a given dosage and temperature is ultimately complete, the appearance of adult beetles showing signs of life at destination would be undesirable.

For most fumigations the caged test insects were placed at 20 standard locations near the side walls within the cars and bunkers. These locations included points at each side of the car, both near the ceiling and on the floor, either on the slatted racks or dropped between the slats. On each side of the car the locations were, in each bunker, just inside the ends of the car adjoining the bunkers, and near the side-door cracks. The top locations were within 10 inches, usually 6 or less, of the ceiling, except that the cages at the car ends generally rested on the bunker ledges. These frequently were supplemented by others distributed over and among the load. In some cars the nature of the load was such that an occasional cage was slightly above instead of on the floor. The 1 by 6-inch, cork-stoppered, cylindrical screen-wire cages used in the vault-fumigation tests were used in all tests involving adult beetles.

The dosages tried in car fumigation are recorded in pounds of methyl bromide per car and are based on an average car volume of 2,500 cubic feet. A dosage of 5 pounds is, for example, the approximate equivalent of 2 pounds per 1,000 cubic feet. In all fumigations of refrigerator cars care was taken in advance to set the hatch plugs tightly and to plug all drip drains from the outside with waste or other material.

The need for mixing the fumigant with the air in the cars was indicated in preliminary results. This is illustrated by the fumigation of an empty car for 2 hours with no circulation, a dosage of 2½ pounds of methyl bromide being sprayed toward with floor within each bunker (5 pounds per car). Two days after fumigation, test beetles from 10 locations near the ceiling averaged 8.8 per cent mortality while those from 18 floor locations averaged 100 per cent.

CAR FUMIGATIONS IN 1937.—In the earliest investigations, mixing of gaseous methyl bromide with air in refrigerator cars was accomplished with a device that utilized the velocity of the gas stream, as furnished by methyl bromide under 50 pounds' pressure, injected through a small orifice into a sleeve equipped with louvers at the base through which air was drawn to mix with the fumigant. The apparatus consisted of two delivery tubes attached to a substantial stand to be placed in the door bracing, one tube directed toward each end of the car. The methyl bromide was heated in the cylinder, immersed in water at 175° F. Connection was made to the applicator through a special hollow door plate which was sealed in the packing of the refrigerator car door when it was closed.

One fumigation with a load of string beans at a temperature range of 84 to 97° F., 5½-pound dosage, gave complete mortality of test beetles both in the vault space and within the hampers of beans. In six fumigations with bagged potatoes as the load, mortality of test beetles within the vault space was complete with a dosage of 4 pounds at 79 to 80° F., incomplete in a second at 78 to 87° F., complete with a dosage of 4¾ pounds at 79 to 87° F., complete in one car with a dosage of 6 pounds at 73 to 76° F., and incomplete in two cars, the one at 71 to 74° and the other at 74 to 77° F. Approximately 13,000 beetles were used in this series. In the cars showing survival this ranged from 7 to 4.5 per cent. Because of the cumbersome equipment and the evident impossibility of achieving uniform complete mortality by the above method, this procedure was discontinued.

CAR FUMIGATIONS INVOLVING JAPANESE BEETLE LARVAE.—In all fumigations but one, subsequent to 1937, circulation and distribution of gas within the cars was accomplished by the use of a motor-driven multivane blower. The blower was suspended in one bunker and directed an air stream into the body of the car through the top bunker screen. The blower used has an air blast rating of 700 cubic feet per minute, free air.

Before the 1938 appearance of Japanese beetle adults, five fumigations were made in empty cars using larvae as test insects. It was believed, and this has since been confirmed, that adults of this insect are more easily killed by methyl bromide than are the immature stages. A discussion of the procedure followed in handling test grubs is omitted except to note that they were segregated during treatment so that none of the mortality was due to fighting.

In one test the mixing and distribution of gas and air was accomplished by two 16-inch oscillating electric fans backed together and set 20 inches above the floor in the middle of the car. A 5-pound dosage of methyl bromide was liberated through a spray nozzle at the ceiling above the fans. Seven days after treatment larval mortality was 99.92 per cent. The methyl bromide used in this and in all subsequent car fumigations was contained in cylinders equipped with siphon tubes and was released as weighed or measured dosages by means of self-generated pressure.

Four cars containing larvae were fumigated at a dosage of 5 pounds per car, the electric blower being hung from the hatch combing and operated during, and for 15 to 20 minutes after, the fumigant release. The methyl bromide was released in the bunker containing the blower through a downward-directed disc-type spray nozzle attached to a quarter-inch copper tube inserted through the hatchway, which was closed with the usual plug. The tube was removed and the plug reset after the release of the dosage.

In these tests, involving over 5,000 larvae, the mortality at the floor locations averaged 99.8 per cent and at the ceiling locations, 93.8 per cent. At the ceiling the mortality was highest in the bunker containing the blower (96.1 per cent) and decreased with the distance away from this bunker to the opposite end of the car where it was 92.2 per cent. The ceiling mortality within the opposite bunker was 92.5 per cent.

CAR FUMIGATIONS OF ADULT JAPANESE BEETLES IN 1938.—In June, 1938, the work was again taken up with adult beetles in loaded cars, mainly of potatoes and onions supplied through the cooperation of the Eastern Shore of Virginia Produce Exchange by arrangement with G. S. Ralston, general manager. All the records which follow were obtained as a result of this cooperation. No especial consideration was given to car temperatures, and a single dosage of 5 pounds per car was used.

In the first car fumigated the procedure used in the experiments on the larvae was followed, that is, with the dosage released through a downward-directed nozzle into one bunker and with the blower in operation during and for 20 minutes after the dosage release. Mortality within 24 hours after fumigation was complete except in the bunkers, and was lowest at the ceiling locations in the bunker containing the blower. The possibility that the period of blower operation was too long and resulted in the drawing in of fresh air through the hatch above the blower was confirmed circumstantially in subsequent tests in all of which the blower was operated for five minutes only, following application of the fumigant. A system of straps and hooks was adopted for supporting the blower in the bunker. By adjusting the length of the straps and the location of the hooks on the hatch combing, it was possible with most types of cars to spot the mouth of the blower against the screen so that it delivered into the body of the car. For commercial use it is essential that any equipment used be removed at the end of the circulation period, so that it will be available for the next car in line without the delay of the entire exposure period. In most of the experimental cars the hatch plug was raised, the blower removed, and the hatch re-closed after the blower was turned off. This procedure required from 6 to 10 seconds.

Six cars loaded with potatoes were fumigated with the blower in operation for 5 minutes after the fumigant was applied and with the nozzle directed downward as discussed above. The only change in procedure was that the dosage was divided. Two pounds were released in the bunker at the car end opposite the bunker con-

taining the blower and through the hatch directly in front of that supporting the blower, and 3 pounds into the bunker containing the blower, through the opposite hatch. Complete mortality was obtained, though on two occasions it was much delayed.

A final change was made in this procedure. An applicator tube was constructed provided with a U-bend which, when inserted into the hatch, directed the nozzle upward and about 1 foot below the car ceiling. With the combination of 5 minutes of blower operation following application of the fumigant, a split 2- and 3-pound dosage as above, and an upward-directed nozzle turned for release toward the center of the bunker ceiling, 14 cars of potatoes and onions were fumigated with mortality complete in every case overnight following fumigation. The data on the last 20 cars for 1938 noted above are shown in table 2. In the table the first 5 cars and car 9 are for the downward-directed nozzle and the remainder for the upward-directed. The beetles in the load in cars 16 to 20, inclusive, were placed in bushel baskets of cucumbers and in crates of green-wrapped tomatoes placed on top of the standard load of potatoes. Mortality of test beetles was complete in every case within the period shown by "days held." The tests are listed in chronological order.

Most of the refrigerator cars used for the movement of vegetables without refrigeration are in a poor state of repair. The cars put into the service are unsuitable for commodities requiring close temperature control. Several of those used in experimental fumigations were in the worst possible condition. The frameworks were weakened, the exteriors broken and cracked, the interiors much battered, and the hatch plugs so dented that it was impossible to seat them properly. The fact that complete mortality was obtained in all cars, regardless of condition, and that this occurred within 24 hours, in all cars in which the methyl bromide was released through an upward-directed nozzle, demonstrates the effectiveness of the treatment.

**Table 2.—Summary of data on fumigation of loaded cars subjected to the divided-dosage schedule, 2 and 3 pounds, 1938. Mortality complete in every test.**

| Car No. | Car Temperature at Start, °F. | Number of Beetles Used | | Days Held | Control Mortality, Per Cent |
|---|---|---|---|---|---|
| | | In vault space | In load | | |
| 1 | 78 | 1,941 | — | 1 | 1.1 |
| 2 | 84.5 | 1,682 | — | 1 | 0.0 |
| 3 | 84 | 1,839 | 240 | 1 | 0.0 |
| 4 | 78 | 1,698 | — | 13 | 13.9 |
| 5 | 83 | 1,731 | — | 13 | 13.9 |
| 6 | 82 | 2,445 | — | 1 | 15.1 |
| 7 | 83 | 2,316 | — | 1 | 15.1 |
| 8 | 76 | 5,829 | — | 1 | 0.9 |
| 9 | — | 6,088 | — | 1 | 2.9 |
| 10 | 76 | 1,921 | — | 1 | 2.9 |
| 11 | 83 | 2,894 | — | 1 | 10.0 |
| 12 | Over 82 | 2,727 | — | 1 | No control |
| 13 | — | 2,787 | — | 1 | 0.0 |
| 14* | 82 | 1,057 | — | 1 | 0.0 |
| 15 | 84 | 2,427 | — | 1 | 21.7 |
| 16 | 86 | 2,220 | 326 | 1 | 23.8 |
| 17 | Over 80 | — | 626 | 1 | 49.0 |
| 18 | Over 80 | — | 694 | 1 | 49.0 |
| 19 | Over 80 | — | 797 | 1 | 49.0 |
| 20 | Over 80 | — | 287 | 1 | 49.0 |
| Total beetles | | 41,602 | 2,970 | | |

* Exposure period of 1½ hours only.

On the basis of the findings shown in table 2 the method for car fumigation was approved by the United States Department of Agriculture (1938) and was put into commercial use by the Pennsylvania Railroad Company in 1938 and by several other railroads in 1939. The procedure outlined above was followed, the down-

**Table 3.—Experimental fumigation of loaded refrigerator cars, at 2-hour exposures, 1939.**

| Dosage, Lbs. per Car | Car Temperature Range, °F. | Number of Beetles Used | Per Cent Mortality | | Days to Complete Mortality | Control Mortality, Per Cent |
|---|---|---|---|---|---|---|
| | | | After 24 hrs. | Final | | |
| 3½ | 84–81 | 9,259 | 97.5 | 100 | 5* | No control |
| 3¾ | 86–79.5 | 7,101 | 100 | | 1 | 12.8 |
| | 81–79 | 2,956 | 100 | | 1 | 7.1 |
| | 79–74 | 12,040 | 100 | | 1 | 14.2 |
| 4 | 84–79 | 6,479 | 100 | | 1 | 21.9 |
| | 72–72 | 6,438 | 100 | | 1 | 12.6 |
| | 73–73 | 5,340 | 99.2 | 100 | 5 | 78.3 |
| Total beetles used | | 49,613 | | | | |

* The whorl disc was inadvertently left out of the nozzle during the release of the fumigant in this test. As a result the fluid was released as a stream instead of as a mist. This omission is believed to be responsible for the delayed complete mortality.

ward-directed release nozzle being used in 1938 and the upward-directed nozzle in 1939. In the two seasons almost 4,000 loaded cars of produce, including white potatoes, sweet potatoes, onions, and tomatoes, were fumigated by railroad crews and shipped to points outside the regulated area.

CAR FUMIGATIONS IN 1939.—Experimental car fumigations in 1939 were directed entirely toward the securing of information on the possibility of reduction of dosage at high temperatures. Seven cars loaded with potatoes were treated at schedules shown in table 3. Test beetles were placed at the 20 standard locations and, in the first five tests, at numerous points between and on top of the bags and barrels as well. All dosages were split, with approximately half liberated into each bunker. Of the seven cars used, one was in good condition, two were regarded as of about average tightness, and the remaining four were among the worst the writers have encountered.

DISCUSSION OF CONTROL MORTALITY.—In many of the car-fumigations recorded above control mortality was high. This should be regarded as a criticism of the technique of handling control beetles rather than as reflection on the vitality of the beetles used in the tests. After being caged in the screen-wire cylinders, the lots for fumigation were treated within a few hours and thereby rendered permanently incapable of feeding. The controls, on the other hand, which received no check on their necessity for food, were held in these cages during fumigation and for the same period thereafter as were the fumigated beetles. Because of unavoidable conditions, this period frequently amounted to from 12 to 24 hours, in many cases at high temperatures. Control mortality is undoubtedly due in large part to this period of enforced starvation.

Abnormally high control mortality could, in a large measure, be forestalled by caging the beetles in larger containers with suitable food. The 1 by 6-inch cylindrical cages, however, are of excellent size and shape for use in testing, since they can be placed in and removed from crowded situations not accessible to larger ones. Furthermore, since the fumigations all resulted in complete mortality of test beetles, the significance of control mortality is minimized.

SUMMARY.—Methyl bromide fumigation of fresh fruits and vegetables has been investigated, and commercial bases for application have been developed for use both in fumigation vaults and in loaded refrigerator cars.

In especially constructed fumigation vaults it has been shown that complete mortality of Japanese beetle adults can be obtained in both vault space and load in fumigations with a 2-hour exposure period, and that dosage is dependent upon temperature. Complete mortality was obtained with dosages of 2 pounds of methyl bromide per 1,000 cubic feet at 65 to 90° F., of 1 pound at 76 to 89° F., and of 0.75 pound at 77 to 86° F. These are the results obtained in experimental fumigations involving 108,000 beetles.

A successful method for fumigating loaded refrigerator cars was developed in 1938 and put into immediate commercial use. The treatment requires the use of a multivane blower with an air blast rating of 700 cubic feet per minute free air, the introduction of a part of the dosage into each bunker of the car, and the release of methyl bromide through a disc-type spray nozzle. As used commercially in 1938 the nozzle was directed downward, and in 1939 upward to discharge toward the ceiling. Work in 1939 indicates that a dosage of 3.5 to 4 pounds per car at temperatures of 80° F., or above, results in complete mortality.

In the experimental car fumigations, over 5,000 grubs and about 110,000 adults of the Japanese beetle were used.

The treatment has been commercially applied to almost 4,000 cars of produce during the 1938 and 1939 seasons of beetle activity.—11-16-39.

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# Survival of Type A Milky Disease of Japanese Beetle Larvae Under Adverse Field Conditions

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INTRODUCTION.—The purpose of this paper is to place on record the results of certain field experiments with the type A milky disease of the grub of the Japanese beetle, *Popillia japonica* Newm., that demonstrated the adaptability of the causative organism to a wide variety of adverse conditions. The milky diseases of the Japanese beetle larva, caused by two species of bacteria, have been assuming a place of increasing importance among the biological aids to the control of the Japanese beetle. Observations on these diseases made during 1933 and 1934 have been published by Hawley and White (1935). Field experiments carried on in southern New Jersey in the spring of 1935 by S. R. Dutky, of the Moorestown, N. J., laboratory, resulted in the establishment of type A milky disease and in a very definite reduction of larval population the same season in the plots in which the diseased larvae had been placed. Further field tests were therefore started by Dr. Dutky in the fall of 1935. Subsequent studies of these plots were made by the author.

LOCATION.—The experiments with the type A milky disease reported in this paper were carried on at the West Chester Golf Course, West Chester, Pa.

A preliminary survey of the roughs was conducted on October 25, 1935, in which survey 2,029 larvae were recovered from a total of 75 one-foot diggings. The soil population on this date was composed of 10 per cent second-instar and 90 per cent third-instar larvae, averaging 27 larvae per square foot but some diggings showing as many as 70 per square foot. Turf injury was extremely severe over most of the course. No milky disease was recovered at the time of this survey. Upon a later examination of these grubs at the laboratory, however, a single infected grub was found which possibly became infected through laboratory handling. The absence or, at least, extremely low incidence of disease at this location made it a favorable one for experiments to determine establishment and subsequent build-up of the disease.

DISEASE PLOTS.—Although it was known at this time that the soil temperature at the three-inch level was below 60 degrees F. (the minimum for development of the causal agent), it was desired to place material in the field in the late fall season, since successful establishment had already been obtained by spring application.

Two plots, each 25 by 25 feet, were treated on October 30, 1935, with living, artificially inoculated *Popillia* larvae. Plot one received 20 diseased living larvae at each fifth foot, in each direction, beginning with the margin of the plots, a total of 720 larvae, while plot two received only 10 such larvae every fifth foot, or a total of 360.

WEATHER DURING THE WINTER OF 1935–36.—The winter was very cold, and during the first half of January five inches of rain fell over the general area, saturating the soil. Immediately after this the temperature dropped to below the freezing point and remained so throughout the latter half of January and the entire month of February. Varying depths of snow covered the resultant ice until late in February, a period of 41 consecutive days, at the end of which period the frost extended to a depth of 24 inches.

The temperature of the soil at the 3-inch level in non-sodded areas free from a snow cover dropped below 15 degrees F. (the temperature previously determined to be fatal to Japanese beetle larvae). In like areas with a snow cover, the temperature was only a degree above this fatal limit.

Winter mortalities approaching 100 per cent were recorded from certain areas, and at the West Chester Golf Course, in March 1936, surveys showed a winter kill of 80.6 per cent. Out of a total of 1,259 grubs dug from 50 one-foot diggings, only 244, or less than 5 per square foot, remained alive, as compared with about 27 per square foot the preceding fall.

This unusual condition, resulting in excessive winter mortality, made impossible the studies that had been planned on immediate establishment and rate of spread of the causal agent of the milky disease, but did make possible an entirely different study, namely, Can the causal agent be

placed in an area ahead of the beetle, or shortly after its arrival in the new area, and be effective in holding the subsequent population to a point at which a minimum of turf injury will result? Since soil temperatures at the time the infected larvae were placed in the soil in October, 1935, prevented further development of the organism, a comparatively small number of spores resulted, and the extremely cold weather thereafter subjected these to a severe test. Since, as previously stated, fewer than five living larvae per square foot remained in the soil in March 1936, the resultant condition was comparable to that which would result from a light dosage of the causal agent in an area only recently infested with the Japanese beetle. The observations, recorded below, demonstrate that the organism will resist adverse conditions of wet and cold, and also that when established in an area of light larval infestation the causal agent will increase as the larval population increases and reduce turf injury in the area in which it is present.

SURVEYS OF PLOTS.—Since the population of larvae in the soil following the severe winter was extremely low, and very few beetles were present during the 1936 season, only two surveys were made during that year. In June the average population was only four larvae per square foot, but in October, with the new brood, there was an increase to eight per square foot. Evidence of disease was noted only in plot two during 1936. Again, because of the low population existing in the soil, no surveys were made during 1937. However, there was a noticeable increase in feeding injury during the 1937 period of beetle activity and larval surveys were resumed in the spring of 1938. A survey conducted on May 6, 1938, before soil temperatures permitted development of any milky disease organisms, showed an average population of 15 larvae per square foot, both within the plots and in close proximity to them, a very definite increase over the number found in the surveys of 1936. A further survey made on June 16, 1938, showed disease present not only within the plots but also in the check areas within 200 feet of them, the population being reduced from 15 to 6 larvae per square foot in the plots and checks alike. It was noted at this time that disease incidence in the two plots was comparable, indicating that any advantage resulting from the heavier dosage applied to plot one three years earlier had disappeared. For convenience, therefore, the two plots will hereafter be treated as a single one and be referred to as the "treated area."

During July and August, 1938, large numbers of beetles were observed and exceedingly severe injury to foliage occurred in the general area. Surveys of grubs in the soil were resumed on August 2, 1938, and continued throughout the remainder of the year 1938 and the spring of 1939. The survey in August showed an average of over 52 grubs per square foot within the area treated with the milky disease agency, with some of the small first-instar larvae already infected. A very noticeable decrease in larval population within the treated area as well as within the immediately surrounding area was accompanied by a marked increase of disease incidence during the following months. On June 12, 1939, only six healthy larvae per square foot remained in the treated area, with disease incidence in plot one reaching 70 per cent and averaging 43.9 per cent. Within a 200-foot radius from limits of the plots, less than 10 healthy larvae per square foot were found, with more than 30 per cent disease incidence occurring at this time.

It was very interesting to observe the increase in larval population as the distance from the treated area was increased. Slight turf injury due to grub feeding was evident on May 16, 1939, near the center of the course, approximately 250 yards from the treated area, where an average of more than 36 grubs per square foot was found. Turf injury increased beyond this point until, at the farther end of the course some 500 yards from the treated area, an average population of 61.6 per square foot occurred and the turf was completely destroyed.

The first larvae infected with the milky disease organism at distances beyond 200 feet from the treated area were recovered on June 12, 1939. On this date less than one per cent disease incidence was noted in the center of the course and approximately 10 per cent in a rough at the far end, 500 yards from the treated area. A local spot in this area showed 40 per cent of the living larvae found on this date to be infected. Birds and skunks had been feeding heavily on the grubs in this area,

**Table 1.—Summary of data from larval surveys conducted at West Chester, Pa., dealing with the 1938 brood of *Popillia japonica*.**

| Location of Diggings | Date of Diggings | Number of 1 by 1 Foot Holes | Total Number of Living Larvae | Number of Living Larvae with Milky Disease | Average per Square Foot | Per Cent Milky at Time of Survey |
|---|---|---|---|---|---|---|
| Treated area | 8/ 2/38 | 8 | 419 | 6 | 52.3 | 1.4 |
| | 8/22/38 | 8 | 248 | 10 | 31.0 | 4.0 |
| | 9/ 2/38 | 8 | 316 | 19 | 39.5 | 6.0 |
| | 10/ 5/38 | 8 | 209 | 5 | 26.1 | 2.3 |
| | 10/31/38 | 12 | 265 | 13 | 22.0 | 4.9 |
| | 5/16/39 | 6 | 156 | 2 | 26.0 | 1.2 |
| | 6/12/39 | 6 | 66 | 29 | 11.0 | 43.9 |
| Check area within 200 feet of plots | 9/ 2/38 | 15 | 590 | 45 | 39.3 | 7.6 |
| | 10/ 5/38 | 8 | 218 | 3 | 27.2 | 1.3 |
| | 10/31/38 | 12 | 339 | 5 | 28.2 | 1.4 |
| | 5/16/39 | 6 | 179 | 0 | 29.8 | 0 |
| | 6/12/39 | 6 | 82 | 19 | 13.6 | 30.4 |
| Check area (center of course) | 9/ 2/38 | 20 | 911 | 0 | 45.5 | 0 |
| | 10/ 5/38 | 4 | 182 | 0 | 45.5 | 0 |
| | 10/31/38 | 12 | 538 | 0 | 44.8 | 0 |
| | 5/16/39 | 6 | 217 | 0 | 36.1 | 0 |
| | 6/12/39 | 6 | 159 | 1 | 26.5 | 0.6 |
| Check area (far end of course) | 5/16/39 | 6 | 370 | 0 | 61.6 | 0 |
| | 6/12/39 | 6 | 228 | 21 | 38.0 | 9.2 |

and because previous work at this laboratory had indicated that the spores of the disease organism pass in a viable condition through the digestive tract of birds and chickens, it was assumed that, as a result of this feeding, diseased larvae would be recovered generally over the entire course when the new brood of larvae was present in the soil. This assumption was substantiated by a survey made on September 19, 1939, when infected larvae were recovered from every section of the course.

Table 1 gives a summary of data from the surveys conducted while the 1938 brood of larvae was present in the soil, and table 2 gives similar records for the 1939 larvae. These data clearly show the reduction of the soil population and the build-up and spread of the causal agent over the entire course.

An extended drought during most of

**Table 2.—Summary of data from larval surveys conducted at West Chester, Pa., dealing with the 1939 brood of *Popillia japonica*.**

| Location of Diggings | Date of Diggings | Number of 1 by 1 Foot Holes | Total Number Living Larvae | Number Living Larvae with Milky Disease | Average per Square Foot | Per Cent Milky at Time of Survey |
|---|---|---|---|---|---|---|
| Treated area | 8/ 1/39 | 5 | 6 | 0 | 1.2 | 0 |
| | 8/31/39 | 6 | 21 | 7 | 3.5 | 33.3 |
| | 9/19/39 | 6 | 14 | 0 | 2.3 | 0 |
| Check area within 200 feet of plots | 8/ 1/39 | 5 | 27 | 0 | 5.4 | 0 |
| | 8/31/39 | 6 | 14 | 0 | 2.3 | 0 |
| | 9/19/39 | 6 | 41 | 7 | 6.8 | 17 |
| Check area (center of course) | 8/ 1/39 | 4 | 13 | 0 | 3.2 | 0 |
| | 8/31/39 | 6 | 67 | 3 | 11.1 | 4.4 |
| | 9/19/39 | 7 | 89 | 9 | 12.7 | 10.1 |
| Check area (far end of course) | 8/ 1/39 | 4 | 39 | 0 | 9.7 | 0 |
| | 8/31/39 | 6 | 39 | 0 | 6.5 | 0 |
| | 9/19/39 | 6 | 54 | 3 | 9.0 | 5.5 |

the summer of 1939 prevented as great a population of larvae in the soil as would normally have occurred with the large number of adults present throughout the summer season. Data in table 2, however, show that the population in the treated area has remained lower throughout the 1939 season than in the untreated areas. It is also evident that the disease has now become generally distributed, and in view of additional unpublished data obtained under similar conditions very little if any injury from grub feeding seems likely on the course in the future. Under normal conditions, a more or less substantial larval population might well be expected during July and August 1940, but with the milky disease organism distributed generally over the entire course a population sufficiently heavy to cause serious turf injury is not expected.

SUMMARY AND CONCLUSIONS.—The introduction of Japanese beetle larvae infected with the type A milky disease organism into field plots in the fall of 1935 resulted in the establishment of the organism, in spite of subsequent extremely abnormal climatic conditions which reduced the larval population to a minimum during the winter months. Likewise, neither the excessively wet condition of the soil nor the extreme dryness prevailing later, at certain times, lessened its effectiveness.

By 1938 conditions permitted a great increase in the abundance of the insect in the general vicinity but in the disease plots the numbers of grubs fell off to a marked extent and the population in these plots continued at a low level through 1939. In 1938 the disease was found as far as 200 feet from the plots and in 1939 it was found in check areas as much as 500 yards away.

No infected larvae were recovered or evidence of the presence of the causal agent found beyond a radius of 200 feet from either plot until June 12, 1939, further strengthening the original assumption that the causal organism did not exist on this course prior to its introduction in the plots on October 30, 1935.

Data indicate that when once the soil becomes highly infectious with the causal agent, no substantial population of Japanese beetle larvae can exist. Serious turf injury can thus be reduced, if not entirely prevented, by the introduction of the causal agent of type A milky disease. A rapid build-up and spread of the organism may be expected when a reasonably heavy larval population occurs.

The ability of this agent to withstand adverse conditions and its permanence when once established emphasize its value as a factor in the economic control of *Popillia japonica*.

It should be possible to introduce the causal agent before the Japanese beetle arrives, or soon after it has reached a given point, and before numbers sufficient to cause injury have become established.

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# Effect of the Introduction of Milky Diseases on Populations of Japanese Beetle Larvae[1]

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INTRODUCTION.—It was known as early as 1921 (Smith & Hadley 1926) that certain diseases existed among larvae of the Japanese beetle (*Popillia japonica* Newm.). The earlier work along this line was limited in scope, however, and not conclusive, and it was not until 1933 that really intensive studies of this factor in natural control of this insect were undertaken. In preliminary investigations Hawley & White (1935) classified diseased

[1] The studies reported in this paper were carried out in part under a cooperative arrangement between the United States Department of Agriculture and the New Jersey Agricultural Experiment Station.

larvae on the basis of gross appearance into three groups: the black group, the white group, and the fungus group. They placed most of the dead larvae found in the field and examined by them in the black group.

Since 1934 studies of numerous diseases affecting Japanese beetle larvae have been carried on by the writers at the Moorestown, N. J., laboratory. Two diseases of the white group, known as types A and B milky disease, have shown the greatest promise for utilization in control. These are produced by two closely related undescribed species of spore-forming bacteria which grow and sporulate in the blood of the living larvae. The spores of these bacteria are produced in large numbers in the blood and give it its characteristic milky appearance. It is to this turbidity that the diseased larvae owe their white color. As many as 20 billion spores have been found in the blood of a single diseased larva. Diseases of the white group were the most prevalent, over 90 per cent of all diseased larvae examined in field studies during the period 1935–36 falling in this group.[2] The extreme hardiness of the organisms causing the milky diseases, as well as the ease with which healthy larvae can be infected with them, at once indicated their value in control of *Popillia* larvae.

DISTRIBUTION AND OCCURRENCE OF THE MILKY DISEASES.—Larval surveys since 1934 have led to the following conclusions in respect to the distribution and occurrence of the milky diseases. In areas recently infested, where the larval infestation is low, no evidence of milky diseases has been found. As the larval infestation develops and approaches a peak, the disease incidence is low, but increases rapidly as the host infestation reaches its peak. Within a few seasons thereafter the disease incidence reaches its peak, and simultaneously an appreciable drop in larval infestation is noted.

In extensive larval surveys in southern New Jersey in 1934 and 1935, prior to the establishment of experimental disease plots in that area, thousands of larvae examined showed no evidence of milky disease infection. Recovery of infected larvae has since been made from all counties in New Jersey except Atlantic County in the south and Sussex, Bergen, Hudson, and Warren in the north.

Examination of some 25 soil samples, containing *Popillia japonica* larvae, from diggings made in Westchester County, N. Y., furnished by D. M. Daniel, of the New York (Geneva) Agricultural Experiment Station, showed no evidence of milky disease in that area. Similar samples and larvae from Concord, N. H., and New Haven, Conn., also failed to show the presence of disease. Out of 100 samples from Maryland, furnished by the State Entomologist of Maryland, 10 showed the presence of type A milky disease, eight out of 54 samples from Cecil County, one out of 14 samples from Kent County, and one out of 3 samples from Prince Georges County. A total of 29 samples taken in Anne Arundel, Baltimore, Baltimore City, Frederick, Harford, Howard, Queen Anne, Talbot, and Worcester counties failed to reveal the presence of milky disease.

INTRODUCTION OF THE DISEASE ORGANISMS IN THE FIELD.—The first problem encountered in laying out the field plots is obtaining diseased material in sufficient quantities. As no artificial medium has been found to date which permits the organisms to develop to the spore stage, it is necessary to use living larvae as the culture medium. A micrometer injection block has been designed which permits the inoculation of large numbers of larvae with accurately determined dosages of spores. The inoculated larvae are incubated in soil at a temperature of 86 degrees F. for 10 to 12 days. By that time the yield of spores per larva averages between 1 and 3 billion, depending on the number of spores in the inoculating dosage.

In the earlier studies the diseased larvae thus obtained were taken to the site of introduction, ground up in a mortar, and added to water to make the necessary spore suspensions. Samples of spore suspensions were taken at the time of application and counts made of these samples to determine the numbers of spores applied to the treated areas.

[2] The apparent inconsistency between the findings of the present writers and those of Hawley and White in their earlier study of the situation in the field is explained by the fact that the material examined by Hawley and White consisted, for the most part, of dead larvae or larvae in the very last stage of infection. On the other hand, the conclusions reached by the present writers are based upon examination of larvae in all stages of infection and upon the condition of the body contents of such larvae, as well as their gross appearance. Very frequently larvae infected with the milky diseases do become definitely dark or blackish in color in the last stage of infection and after death; and, on the basis of gross appearance only, such larvae might easily be thought to have been killed by diseases of the so-called black group.

Recently, however, this work has been simplified considerably by taking advantage of the resistance of the causal agent to drying. The diseased larvae are now ground up in the laboratory and used to impregnate powdered talc. The impregnated talc is then reground and dried. By this method it is possible to keep on hand at all times a supply of infectious material which has been carefully standardized by spore counts and infection tests. The spore-talc mixture can be applied either as a water suspension or as a dust.

Various methods have been employed for introducing the disease agents. Living inoculated larvae have been planted in the plot areas. Spore suspensions, spore-talc dusts, and infectious soil have been applied, both continuously and in spots.

Prior to the introduction of the disease agent surveys of the general areas are made to determine the density of the existing larval population and whether milky diseases are present. After introduction periodic surveys are made of both treated and check areas at intervals of about 2 weeks throughout the period of active disease development, which occurs when the soil temperature is above 60 degrees. In the vicinity of Moorestown, N. J., this period extends from the middle of May until the middle of October. All larvae recovered are examined and the presence of diseased larvae is confirmed by microscopic examination of blood smears from all larvae recorded as diseased.

STUDIES IN 1935, 1936, AND 1937.—Preliminary studies conducted during the period 1935–37 within a limited area in New Jersey showed that successful establishment of both type A and type B milky diseases could be easily obtained by any of the methods of application tried. Relatively heavy dosages of infectious material were used in these earlier attempts at introduction and it was concluded that much lighter dosages might be applied. Also it did not appear necessary to treat the entire area to insure establishment and subsequent increase of the disease.

STUDIES IN 1938 AND 1939.—In 1938 and 1939 a total of 45 plots were treated with the type A agent and 10 with the type B agent. The plots ranged in size from 6 by 12 feet to over 2½ acres. They were located over an area extending from Cape Charles, Va., north to Staten Island, N. Y., and west to Reading, Pa., and represented a wide variety of conditions such as soil types, moisture, and temperature. Surveys prior to treatment showed substantial larval populations in each plot.

Various methods of treatment, as well as dosages of the inoculum and intervals of application, were used to determine the minimum amount of material required. Dosages ranging from a minimum of 25 million to a maximum of approximately 1500 million spores per square foot were used. Successful establishment of the disease in the field resulted from all dosages tried. Reduction of the larval population to a point where no serious turf injury will occur can probably be obtained at any of these dosages, in one season or in several seasons,[3] depending upon the distance between points of application.

Larval reductions of over 90 per cent have been demonstrated in certain field plots during a single season. At Cape Charles the larval population was reduced from an average of 121 to 6 healthy grubs per square foot during the period from July to September 1939. In the corresponding check area about 74 healthy larvae per square foot remained at the end of that period. Similar reductions have resulted in plots containing smaller populations.

During the course of field studies it has been possible to hasten materially disease build-up and subsequent larval reduction by applying the disease agent in areas where the disease already occurred. It has likewise been possible to prevent the increase of larval populations to their normal peak by introducing the causal agent into areas where the disease does not occur naturally. Once the disease is introduced into an area it seems to be permanently established.

NATURAL DISPERSION OF MILKY DISEASE.—Field and laboratory observations have proved definitely that birds and insects are important agents of dispersion of this disease. It was determined in experiments in which chickens as well as starlings were fed milky diseased larvae that viable spores were voided in the droppings, with no effect upon either species of bird. Likewise bird droppings that had not been in contact with the soil were collected from the field and shown to con-

[3] The term "season" here refers to any one feeding season of the larvae. Each larval brood has two distinct feeding seasons, fall and spring.

tain viable spores of the type A disease.

Ants have been observed dragging dead diseased grubs for distances of at least 10 feet, an indication of the role played by these insects in local spread of the disease.

Skunks, moles, and mice are in all probability carriers of the disease, as they are known to feed readily upon larvae.

Movement of top soil by wind, water, or man must also play an important part in the spread of this agent, both locally and to distant points.

SUMMARY.—Studies conducted at the Moorestown, N. J., laboratory during the period 1935–39 have shown that milky diseases of the Japanese beetle (*Popillia japonica*) are playing an important role in reducing populations of these larvae.

Surveys and examinations of soil samples from areas in which the larvae had not yet become abundant failed to show the presence of the agents causing these diseases.

Living grubs were used as a culture medium, since to date no artificial medium has been found which permits the organisms to develop to the spore stage. Such grubs, inoculated with the causal agent and held 10 to 12 days at a temperature of 86 degrees F., contained approximately 1 to 3 billion spores. These diseased grubs were then ground and either diluted with water for immediate application or incorporated with powdered talc for storage.

Numerous methods of treatment, including various dosages of the inoculum and intervals of application, were used in field studies. Dosages of about 25 million to 1500 million spores per square foot, applied continuously and in spots, resulted in successful establishment and subsequent build-up of the disease.

Field and laboratory observations showed that birds and insects are important natural agents of dispersion of this disease.—11-16-39.

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# Inexpensive Japanese Beetle Traps

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Traps have been used in Maryland for Japanese beetle control and retardation since 1927. During the early work, due to the limited number of Japanese beetle infestations, the state, cooperating with the Bureau of Entomology and Plant Quarantine, was able to trap all known infestations with the funds available but as the number of infestations increased and the demand for additional traps in heavily infested areas increased, the problem of financing the purchase of traps became acute.

It was believed that if traps were to be used successfully for Japanese beetle control, the following conclusions had to be accepted:

1. Trapping for Japanese beetles should be, for best results, a cooperative endeavor.

2. Traps, to be effective, should be used in sufficient numbers to catch large quantities of beetles.

Considering the cooperative spirit and general interest of Maryland people in traps, it was believed the one fundamental requisite for obtaining the needed number of traps in heavily infested areas, was an efficient and cheap trap.

During the eleven-year period since 1927 the State has purchased Japanese beetle traps from time to time but, prior to 1939, never paid less than one dollar for a complete trap that would hold one gallon of beetles. At this price it was not practical for either the governmental agencies or the people, especially farmers, to cooperate in buying the numbers of traps needed to obtain effective results.

In 1938, in an attempt to provide a cheap trap which would meet Maryland's needs, a series of investigations was started. It was assumed that the color combination and fundamentals of design recommended by the federal department were essentially correct. Therefore, these

features were followed, in the main. In all phases of the investigations, ideas and methods of other research workers were borrowed and freely used.

DEVELOPMENT OF TRAPS.—At the beginning of this study there were two traps recommended, and in general use by governmental agencies. One was a control trap, government patent No. 1968954, and the other was a scouting trap. The control trap was in general use in Maryland but the initial purchase price was too high for practical use in large scale control operations. The bulkiness of the trap was a disadvantage in storage and transportation. The need for repair was frequent, as its many joints, which were usually soldered or spot welded, were easily broken. Moreover, the scouting trap, an unassembled cheap trap, was not thought to be large enough for control purposes.

It was believed that it would be wise to incorporate the fundamentals of the scouting trap into a trap the size of the patented control trap. This would result in economies in construction by elimination of several steps in assembling. The cost of transportation and storage would also be reduced.

In analyzing the construction of these traps it was found that if the angle of the funnel pitch in the control trap was changed from 45 degrees to 60 degrees, the amount of metal in the funnel could be reduced from 152 square inches to 98 square inches. It was also found that if the scout-trap type of baffle was used the amount of metal in the baffles could be reduced from 114 to 91 square inches. Assembling the control trap by the manufacturers was unnecessarily expensive. By incorporating the type of baffles used in the scouting trap, with the savings in metal and a change in the size of the rod or standard, an unassembled trap with the same general features as the control trap could be produced 60 per cent cheaper than the standard trap used heretofore. Such a trap is designated hereafter as the Maryland 1939 trap. The result of the study of the amount of metal required to construct the above traps is given in table 1, and illustrated in figure 1.

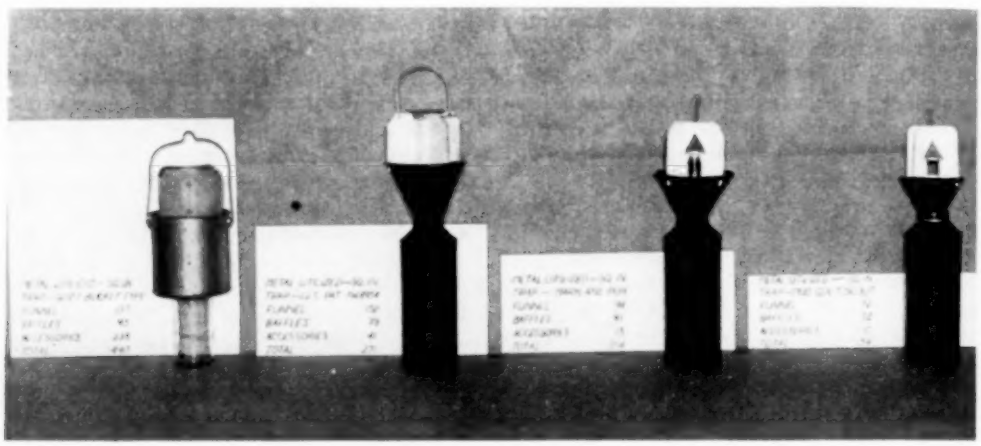

FIG. 1.—Metal required for building trap. Beetle containers not included in calculations. Traps from left to right: bucket type, control, Maryland 1939, and scout. White cards illustrate comparative amounts of metal in each trap.

The University of Maryland, in its cooperative Japanese beetle program, has been able during the past two years to reduce the purchase price of a complete gallon trap from $1.00 to 27½ cents without materially affecting efficiency of the trap. The modifications resulted in a saving of $30,000.00 in 1939. Additional changes made this year will have a minimum value of $6,240.00 in the 1940 program. In order to study the efficiency of this Maryland assembled trap, and to investigate other changes which might reduce cost and improve efficiency of traps, a series of experiments was undertaken, and indications are that the applications of certain findings will be extremely valuable in large-scale control operations.

EXPERIMENTAL PROCEDURE.—All traps,

**Table 1.—Analysis of metal required for Japanese beetle trap construction.**

| Trap Type | Square Inches of Metal Required to Build Trap | | | | | | | | Actual Square Inches of Metal in Trap |
|---|---|---|---|---|---|---|---|---|---|
| | Baffles | Funnel | Container Attachments | Bait Cylinder | Bait Cover | Bucket | Other | Total | |
| Government Bucket | 95 | 157 | | | | 155 | 83 | 490 | 447 |
| Government Patent 1968954 | 78 | 152 | 5 | 36 | | | | 271 | 225 |
| Maryland 1939 | 91 | 98 | 5 | | 10 | | | 204 | 171 |
| Government Scout | 72 | 72 | | | 10 | | | 154 | 122 |

trap parts, and varying factors were tested under field conditions in groups or batteries. A "battery" consisted of a series of different traps spaced six feet apart in a row. At each observation each trap was shifted or rotated in such a way that it occupied each position in the battery at some time. The last trap was always shifted to the first position in the series. In each series of tests batteries were replicated one or more times with each replication situated in a different field or in a different part of the same field. All factors except the one being tested were kept constant. Table 2 gives the specifications of traps investigated in these tests.

TRAP INVESTIGATIONS.—The results of a study of the efficiency of the Maryland 1939 trap, as compared with the government control trap, and the government scout trap are given in experiment No. 1, table 3, and illustrated in figure 2. The government control trap was the least efficient of the three traps. It averaged only 0.87 quart of beetles per day during the experimental period. The government scout trap averaged daily 0.97 quart, while the Maryland 1939 trap averaged 1.06 quarts. In 124 observations, the Maryland 1939 trap caught the most beetles on 53 occasions, the government scout trap caught the most on 43 occasions, while the government control trap caught the most on 9 occasions.

**Table 2.—Specifications for Japanese beetle traps.**

| Trap | | | Funnel | | | | | Baffle | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Diameter | | Color | | | | |
| Name | Illustration | Construction | Degree Angle Pitch | Top | Aperture | Inside | Outside | Kind | Sq. in. baffling surface | Color |
| Maryland, 1939 | Fig. 2 | Unassembled | 60 | 7 | $\frac{3}{4}$ | green | green | 4-winged | 126 | white |
| Maryland, 1939 type (inside funnel white) | — | Unassembled | 60 | 7 | $\frac{3}{4}$ | white | green | 4-winged | 126 | white |
| Maryland, 1939 type (treated cardboard) | Fig. 3 | Unassembled hand made | 60 | 7 | $\frac{3}{4}$ | white | green | 4-winged | 119 | white |
| Government Scout | Fig. 2 | Unassembled | 60 | 6 | $\frac{3}{4}$ | white | green | 4-winged | 108 | white |
| Wooden | Fig. 3 | Assembled hand made | 45 | 7 | 1 | white | green | 4-winged | 126 | white |
| Maryland, 1939 type (1 in. funnel aperture) | — | Unassembled | 60 | 7 | 1 | white | green | 4-winged | 126 | white |
| Government Control Pat. 1968954 | Fig. 2 | Assembled | 45 | 7 | $\frac{3}{4}$ | white | green | 4-winged | 123 | white |
| Maryland, 1939 type (funnel angle 80 degrees) | Fig. 6 | Unassembled | 80 | 7 | $\frac{3}{4}$ | white galvanized | green galvanized | 4-winged | 126 | white galvanized |
| Maryland, 1939 type (galvanized) | Fig. 5 | Unassembled | 60 | 7 | $\frac{3}{4}$ | metal aluminum | metal aluminum | 4-winged | 126 | metal aluminum |
| Government bucket type (aluminum painted) | Fig. 5 | Assembled | 40 | 7 | $\frac{3}{4}$ | painted | painted | 4-winged | 119 | painted |
| Small 4-winged baffle type | Fig. 4 | Assembled | 60 | $5\frac{1}{2}$ | $1\frac{1}{8}$ | green | green | 4-winged | 80 | white |
| Small inverted cone baffle type | Fig. 4 | Assembled | 70 | $5\frac{1}{2}$ | $\frac{3}{4}$ | green | green | inverted cone | 23 | white |
| Small half-circle, single baffle type | Fig. 4 | Assembled | 65 | $4\frac{1}{2}$ | $\frac{1}{2}$ | green | green | 1-wing | $15\frac{1}{4}$ | green |

**Table 3.—Data showing comparative efficiency of Japanese beetle traps.**

| TRAP | NO. OBSERVATIONS | NO. TIMES RANKING FIRST IN CATCH | NO. TIMES TYING FOR FIRST CATCH | TOTAL QUARTS OF BEETLES CAUGHT | AVE. NUMBER QUARTS CAUGHT PER TRAP PER DAY |
|---|---|---|---|---|---|
| *Experiment No. 1. 5 Batteries operated 3¼ days* | | | | | |
| Maryland 1939 | 124 | 53 | 18 | 198.96 | 1.17 |
| Government Scout | 124 | 43 | 19 | 188.99 | 1.11 |
| Government Control (Pat. No. 1968954) | 124 | 9 | 2 | 129.86 | .76 |
| *Experiment No. 2. 5 Batteries operated 15 days* | | | | | |
| Maryland 1939 | 55 | 40 | 5 | 79.54 | 1.06 |
| Galvanized (Maryland 1939—not painted) | 55 | 7 | 6 | 48.37 | .64 |
| Government Bucket Type (aluminum painted) | 55 | 2 | 1 | 44.73 | .54 |
| *Experiment No. 3. 2 Batteries operated 21 days* | | | | | |
| Maryland 1939 | 20 | 17 | 2 | 14.83 | .35 |
| Government Control (Pat. No. 1968954) | 20 | 1 | 2 | 9.26 | .22 |
| Small, 4-Winged Baffle | 20 | 0 | 0 | 4.89 | .11 |
| Small, Inverted Cone Baffle | 20 | 0 | 0 | 1.58 | .04 |
| Small, Half-Circle Baffle | — | — | — | Some beetles | — |
| *Experiment No. 4. 5 Batteries operated 23 days* | | | | | |
| Maryland 1939 | 60 | 9 | 4 | 60.54 | .52 |
| Maryland 1939 (treated cardboard) | 60 | 30 | 4 | 81.84 | .71 |
| Government Control (Pat. No. 1968954) | 60 | 6 | 4 | 42.90 | .32 |
| Wooden (home made) | 60 | 9 | 1 | 49.92 | .43 |

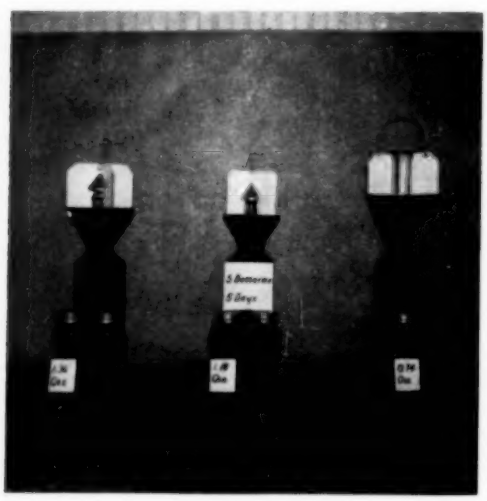

FIG. 2.—Results obtained in one test on the comparative efficiency of traps. Traps left to right are Maryland 1939, modified scout and control. Beetles in quart jars represent the average daily catch of each trap.

In an endeavor to find a material cheaper than metal for trap construction, traps the same size and construction as the Maryland 1939 trap were made of paraffin-treated, painted cardboard. These traps were apparently just as effective in catching beetles as the Maryland 1939 trap but they had a tendency to fall apart under weathering. The results obtained are given in experiment 4, table 3, and illustrated in figure 3. Cheap materials, other than metal, for use in trap construction should be thoroughly investigated for a very cheap trap that will function efficiently for one season might be more desirable than a more expensive trap that would last longer. In the interest of boys who wished to make traps from wood, home made wooden traps were tested. They were approximately 17.4 per cent less effective than the Maryland 1939 trap.

The efficiency of several other traps of smaller size than the government scout trap was investigated. Included in the investigation were traps with four-winged baffles, inverted-cone baffles and single half circle baffles. The best of these traps

was the four-winged baffle type. Even it was only 31.1 per cent as effective as the Maryland 1939 trap. The data pertaining to the efficiency of these traps are given in

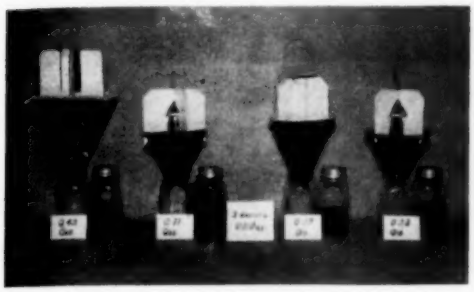

FIG. 3.—Experiments showed wooden and cardboard traps to be effective for catching beetles. Their efficiency is compared with the Control and Maryland 1939 traps. The average number of quarts of beetles caught daily is shown on cardboard signs.

experiment No. 3, table 3, and illustrated in figure 4.

Several years ago L. H. Worthley used, as an economy measure, aluminum paint for reconditioning traps. Since the color of galvanized metal is similar to that of aluminum paint, tests were made with traps made from galvanized metal, with the thought that an efficient unpainted trap might be developed. Galvanized traps were compared with the Maryland 1939 trap and with the aluminum painted government bucket type. The results of the study are given in table 3, and illustrated in figure 5. Neither the galvanized nor the bucket-type was as effective as the green and white Maryland 1939 trap. The galvanized trap was 50.9 per cent less effective than the white and green painted

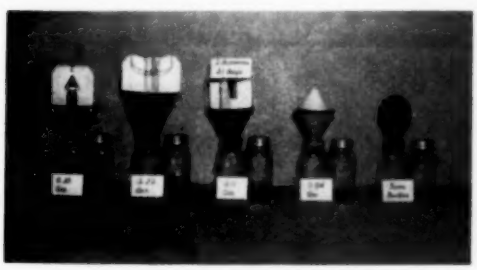

FIG. 4.—A study of the relative efficiency of very small traps as compared with larger traps. The average daily catch of each trap is noted on the cards. Traps from left to right are: Maryland 1939, Government Control, a small 4-winged Baffle type, a small inverted cone baffle type, and a small half circle single-baffle type.

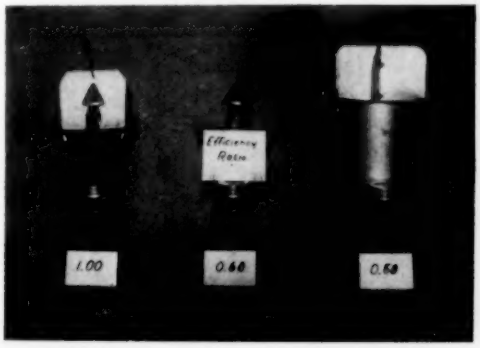


FIG. 5.—A study of the comparative value of the Maryland 1939, the galvanized and the aluminum-painted bucket type traps. For each quart of beetles the Maryland 1939 trap catches in a given time, the galvanized trap catches 0.60 quart, and the aluminum-painted bucket type catches 0.50.

trap. The aluminum painted bucket-type trap was 60.3 per cent less effective.

FUNNEL PITCH.—It was formerly believed that a trap to be most efficient needed a funnel with a 45-degree angle, but this angle requires 35.5 per cent more metal. Field tests of 45, 60 and 80 degree funnels disclosed that the 60-degree angle was the most efficient of the three. The 60-

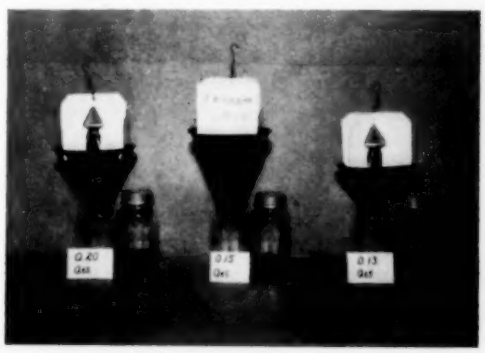

FIG. 6.—The angle in the funnel pitch affects the efficiency of Japanese beetle traps. The above traps from left to right have funnels with angles of 60, 45 and 80 degrees. The average daily catch for these traps is given on the cardboard signs.

degree pitch, utilized in the Maryland 1939 type trap caught 25 per cent more beetles than the 45-degree funnel of the standard government trap. The most reasonable explanation of this greater efficiency of the 60-degree funnel is that the larger space provided in the 45-degree trap provides more opportunities for falling beetles to regain their equilibrium and

fly out of the trap. The details of these experiments are shown in table 4, and figure 6.

INSIDE FUNNEL COLOR.—It has been recommended that the green funnel in Japanese beetle traps be painted white on the inside for maximum trap efficiency. This is a costly operation in relation to the total cost when applied to cheap traps. Therefore, it was thought desirable to weigh experimentally the cost factor against the efficiency factor. Comparative tests were made to determine the difference in efficiency between white and green for inside funnel color. The results of the tests are given in table 4. Traps with funnels painted white inside, in 106 observations, ranking first in catching beetles on 51 occasions. Funnels painted green inside ranked first on 48 occasions. The average daily beetle catch for traps with the funnels painted white inside averaged 1.05 quarts of beetles per day. The traps with the funnel painted green inside averaged 1.06 quarts of beetles per day.

FUNNEL APERTURE SIZE.—The bottom aperture in traps commonly purchased varies widely in size. Complaint of beetles escaping from traps with large openings has been frequent. In order to obtain definite information on the size of opening at the bottom of the funnel, comparisons were made of two diameters. The Maryland 1939 trap, with an aperture of three-quarters inch, was used as the standard. This trap caught, on the average, more beetles than the trap with an aperture of one inch. In 106 observations the traps with the three-quarter inch aperture caught the greater number of beetles on 78 occasions while the traps with one inch aperture caught the greater number of beetles on only 18 occasions. The average catch for the three-quarter inch opening was 0.61 quart per day, while the average catch for the larger opening was .44 quart per day. The detailed results are given in table 4. Figure 7 illustrates variation in size and variation in funnel aperture.

BEETLE CONTAINERS.—Almost any well ventilated container is suitable for holding beetles. Several types have been used in Maryland. Those found to be most suitable are long and narrow, with a sufficiently large opening to permit easy removal of the beetles. Figure 8 illustrates both desirable and undesirable containers. Containers A and B are undesirable because of the comparatively small opening for re-

**Table 4.—Data showing the effect of miscellaneous factors on the efficiency of Japanese beetle traps.**

| Factor | No. Observations | No. Times Ranking First in Catch | No. Times Tying for First Catch | Total Quarts of Beetles Caught | Ave. Number Quarts Caught per Trap per Day |
|---|---|---|---|---|---|
| *Funnel Pitch. 3 Batteries operated 11 days* | | | | | |
| 60-degree angle | 15 | 4 | 6 | 6.79 | .20 |
| 45-degree angle | 15 | 3 | 7 | 5.16 | .15 |
| 80-degree angle | 15 | 1 | 5 | 4.22 | .13 |
| *Inside Funnel Color. 12 Batteries operated 1¼ days* | | | | | |
| White Inside | 106 | 51 | 7 | 176.06 | 1.05 |
| Green Inside | 106 | 48 | 7 | 177.96 | 1.06 |
| *Funnel Aperture. 12 Batteries operated 1¼ days* | | | | | |
| ¾ inch opening | 106 | 78 | 10 | 102.48 | .61 |
| 1 inch opening | 106 | 18 | 10 | 74.53 | .44 |
| *Trap Height from Ground. 5 Batteries operated 13 days* | | | | | |
| 3½ feet from ground | 60 | 32 | 8 | 78.69 | 1.21 |
| 4½ feet from ground | 60 | 17 | 6 | 70.09 | 1.08 |
| 5½ feet from ground | 60 | 3 | 4 | 55.67 | .85 |
| *Wick Height—One-Half Inch Above Stopper. 5 Batteries operated 12 days* | | | | | |
| ½″ cotton | 50 | 32 | 5 | 54.00 | .90 |
| ¼″ cotton | 50 | 10 | 6 | 44.01 | .73 |
| 5/16″×½″ felt | 50 | 2 | 2 | 31.87 | .53 |

Figure 7 illustrates variation in size and variation in funnel aperture.

BEETLE CONTAINERS.—Almost any well ventilated container is suitable for holding beetles. Several types have been used in Maryland. Those found to be most suitable are long and narrow, with a sufficiently large opening to permit easy removal of the beetles. Figure 8 illustrates both desirable and undesirable containers. Containers A and B are undesirable because of the comparatively small opening for re-

moving beetles. Containers C and D are much more desirable. Container C has the same size opening as A and B, but the neck of the container is made so that it provides a funnel for emptying. Container D does not have a funnel shaped opening, but the opening is large and the shoulders narrow. This container is the cheapest of those illustrated.

TRAP HEIGHT.—Tests were made to determine the effect of height from ground on the efficiency of traps. Traps were tested at $3\frac{1}{2}$, $4\frac{1}{2}$ and $5\frac{1}{2}$ feet from the ground. The average quantities of beetles caught per day were as follows: traps $3\frac{1}{2}$ feet from the ground, 1.21 quarts; $4\frac{1}{2}$ feet from the ground, 1.08 quarts; $5\frac{1}{2}$ feet from the ground 0.85 quart. In sixty observations the traps $3\frac{1}{2}$ feet from the ground caught the greatest quantity of beetles on 32 occasions while those at $4\frac{1}{2}$ feet did so on 17 occasions. Traps $5\frac{1}{2}$ feet caught the most on only three occasions. Table 4 gives the data in detail. These results indicate that it is biologically, and economically, to use a short rod for holding traps.

RODS.—During the past year search has been made for cheaper materials for rods to hold traps. Results obtained from using 50,000 rods made of a No. "0" gal-

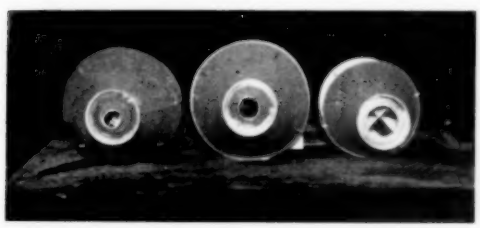

FIG. 7.—The diameter of the aperture in the bottom of trap funnels affects the efficacy of the trap. Note on the variation in aperture size found in traps.

vanized wire indicate that this size wire is satisfactory for holding control traps. This material was used to replace a 7/16 inch iron rod, 84 inches long with seven inches of the upper end bent into an arm. The new rod is made from a 66 inch wire with the upper 6 inches bent into an arm. By using wire the cost of rods was reduced from 19 cents to $7\frac{1}{2}$ cents each. The wire rod is much lighter to handle and to transport.

WICKS.—In the past, the Bureau of Entomology and Plant Quarantine has used, or recommended, quarter-inch and

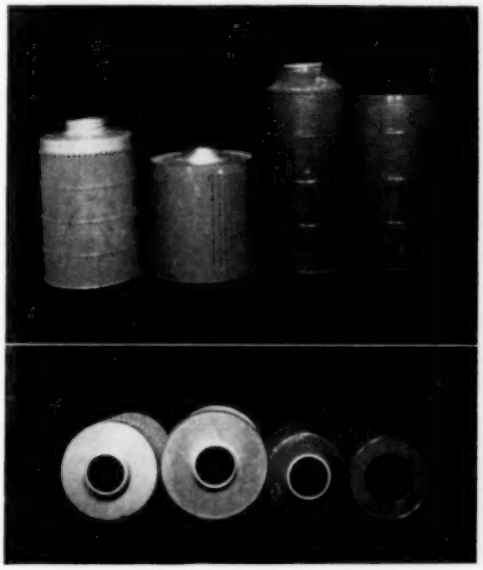

FIG. 8.—Containers in use in Maryland for Japanese beetle traps. Considering the containers from left to right as A, B, C, & D, containers C & D are most satisfactory.

half-inch round, cotton wicks, and five-sixteenths inch by one-half inch felt wicks. All of these wicks have been used in Maryland and found to be efficient if properly adjusted. In large scale operations it is difficult to get operators to adjust wicks properly. Regardless of instructions, a majority of the operators persist in adjusting the wick from $\frac{1}{4}''$ to $\frac{1}{2}''$ above the bait bottle stopper. Of the three, the one-half inch round cotton wick proved to be the most efficient. The results obtained are given in table 4, and illustrated in figure 9.

THE MARYLAND 1940 TRAP.—As a result of the above investigations, there has been assembled a small trap of the same general specifications as the government scout trap. This trap has been fitted with a gallon container for holding beetles. In the field it will be supported by a No. "0" galvanized wire rod sixty inches in length, exclusive of the arm. The arm is approximately five inches long. This particular trap is approximately ten per cent less efficient for catching beetles than the Maryland 1939 trap, but is 31.2 per cent cheaper. The Maryland 1939 trap cost approximately 40 cents. The new trap will cost about $27\frac{1}{2}$ cents. This trap is illustrated in Figure 10. Note that spring

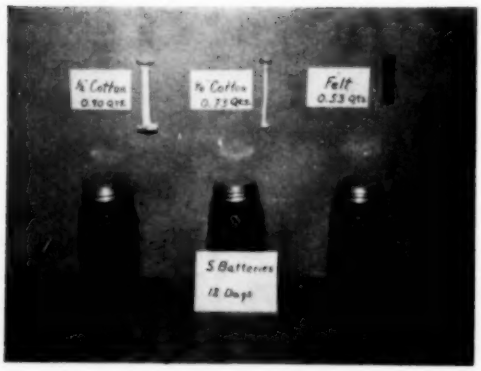


FIG. 9.—Bait wicks in common use. When the above wicks are extended one-half inch above the bait bottle stopper, the one-half inch cotton wick was most efficient. The average daily beetle catch for the above wicks, in a 5-battery experiment, is noted at the left of each wick.

steel wire is used for attaching beetle container to trap.

SUMMARY.—It is believed that the trapping of Japanese beetles should be a cooperative endeavor. To secure effective cooperation cheap traps are essential.

The investigations leading to the development of a cheap trap, with no loss of efficiency, are reported herein. The changes and economies made in design and construction of the Maryland 1939 trap effected savings that had a monetary value of $30,000 to the 1939 Maryland program.

Comparative studies on the efficiency of this trap, the government control trap, Patent No. 1968954, and the federal scouting trap, showed the government control trap was the least efficient of the three. The Maryland 1939 trap was approximately 10 per cent more efficient than the federal scouting trap.

In a search for cheap materials, traps made of wood, and traps of paraffin-treated and painted cardboard, were tested. Both were efficient, but the paper traps were too fragile.

Unpainted, galvanized iron traps were compared with aluminum-painted and green and white painted traps. The latter were enough more efficient to pay for the cost of painting. Painting the inside of the funnels white was only slightly more effective than painting it green.

Traps having a 60 degree funnel pitch were more effective than 45 or 80 degree funnels, and a three-quarter inch bottom aperture was much more effective than a one-inch aperture.

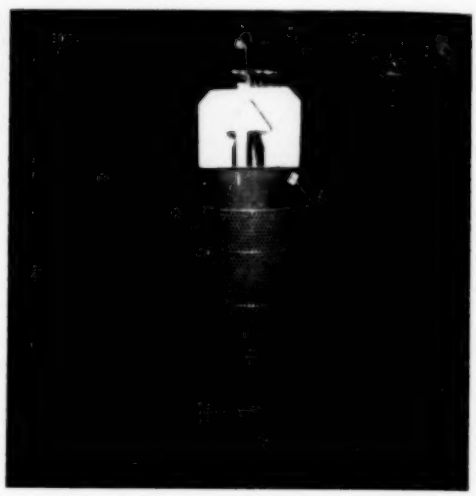

FIG. 10.—The Maryland 1940 Japanese beetle trap Note method of attaching beetle container.

A supporting rod of No. 0 galvanized wire, 66 inches over all was developed that was purchased for 7½ cents, a saving of 11½ cents over the original type. Investigations disclosed that traps suspended 3½ feet from the ground were more efficient than those suspended at 4½ and 5½ feet.

The one-half inch tubular cotton wick was more efficient than the one-quarter inch tubular wick or the felt pads under the average conditions in the large scale trapping where indifferent attention to length of wick exposed was the rule.

A new unassembled trap of high efficiency, with a one-gallon beetle container, complete except for bait, can be manufactured and delivered for 27½ cents.—11-16-39.

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IN A REVISION of the alfalfa weevil quarantine of the State of Wisconsin, which became effective January 15, 1940, new areas placed under regulation included Yuma County, Ariz., Larimer and Pitkin Counties, Colo., Big Horn County, Mont., and Morrill and Sheridan Counties, Nebr.

# The Value of Traps in Japanese Beetle Control

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*University of Maryland, College Park, Maryland*

In Maryland there is in operation a large scale, state-wide cooperative Japanese beetle retardation program. The cooperating agencies include the University of Maryland, the Bureau of entomology and Plant Quarantine, and the local county governmental agencies. In the execution of this program, the cooperating agencies have worked along the following lines: trapping, spraying, dusting, soil treatments, biological control and agricultural adjustment.

Traps have been used without reservation in this program. During this past summer (1939) approximately 100,000 traps were used with the result that more than 1,737 barrels, or 104 tons, of beetles were caught.

It is true that traps will catch large numbers of beetles, but information on their actual effectiveness is extremely scarce. The problem of analyzing the value of traps is so enormous that, with limited funds, it is almost impossible to secure sufficient data to warrant a conclusive statement. Almost any analysis of the situation must be based, in part, on theory. Theory should have a definite place in scientific records if it is supported by sufficient information to stimulate constructive thought or action which may ultimately lead to a correct solution.

Public Opinion.—The people of Maryland approve the use of traps and believe they are efficient in lessening Japanese beetle damage. A survey this past summer, in which approximately 15,000 questionnaires were used, indicated that 93.59 per cent of the people in Maryland using traps favored the program and wanted it continued. Only 6.41 per cent were opposed to the program, or were non-committal.

Experimental Area.—During the summer of 1938 a demonstration area involving 18.8 square miles, or 12,032 acres, was established in Cecil County for the purpose of studying the usefulness of traps. Each farmer in the area was asked to use traps at the rate of one for each acre of land on his farm. Due to delays in trap manufacture and other causes, only 178 farmers with 6,749.5 acres of land used traps. These farmers trapped approximately 35.5 tons of beetles, and 95.4 per cent of the farmers were convinced that traps were effective in reducing crop losses.

Method of Analysis.—It was originally planned to evaluate the effectiveness of the traps through grub population surveys made before and after trapping, but after giving careful thought to this method, it seemed advisable to consider other means for measuring efficiency. Even when a fall grub population survey shows a reduction over a spring survey, it cannot be definitely stated that traps are responsible. Some unknown, or unrecognized biological factor may be the cause. Then, too, it is questionable whether enough is known at present about the relationships which may exist between beetle abundance, egg laying and hatching, and grub survival, to differentiate trap efficiency accurately on the basis of grub counts. Theoretically, 94 out of every 100 beetles might be trapped and still enough eggs might be laid and grubs hatched to provide an increase in beetle population the following year. In such case, traps might be quite effective in controlling adults, but be of little or no value in reducing the grub population in the soil. Even if there is an increase in grub population in the soil this does not eliminate the usefulness of traps when they are effective in reducing damage from the adults.

It seems logical that if the actual beetle population in any large area could be determined and compared with the total number of beetles caught by traps in that area, the result would be indicative of the efficiency of the traps.

It is fairly simple to set traps and record the number of beetles caught, but to determine, with any degree of accuracy, the total number of beetles produced on any farm or in any area is not so easy. It is not practical to count adult beetles on a property or farm to determine this. The most available source of information on potential beetle population in an area is grub abundance in late spring. Therefore, in this analysis, grub populations are the

**Table 1.—Statistics of data collected in 1939 survey to determine ratio of grub populations in pasture land to grub populations in other lands. Sixteen farms, containing a total of 2,615 acres, were surveyed. The average number of samples taken on each farm was 67. Farms were selected at random, but approximately one farm for each square mile in the trapped portion of the demonstrational area was surveyed.**

| Crop | Variation in Grubs per Square Foot | | | Ratio Grub Populations in Pasture Land to Other Land |
|---|---|---|---|---|
| | Maximum | Minimum | Average | |
| Pasture | 53 | 0 | 11.0 | 1.00000 |
| Mixed hay, timothy and clover | 63 | 0 | 8.1 | 0.57857 |
| Corn | 47 | 0 | 8.7 | 0.62142 |
| Alfalfa | 35 | 0 | 8.6 | 0.61428 |
| Orchard | 16 | 0 | 3.0 | 0.21428 |
| Wheat and rye | 7 | 0 | 0.9 | 0.06428 |
| Barley and small grain | 10 | 0 | 0.7 | 0.05000 |
| Soybeans | 20 | 0 | 4.2 | 0.30000 |
| Idle land | 17 | 0 | 4.8 | 0.34285 |
| Wood lot forest and non-agricultural land | 1 | 0 | 0.2 | 0.01428 |

basis for determining probable beetle production, or abundance. In the spring of 1938 it was determined by sampling 450 square feet on 75 farms, that the pasture land in the demonstration area averaged 11.87 grubs per square foot.

In any beetle-infested territory, surveys show that grubs are more abundant in certain types of land cover than in others. There is generally a direct relationship between the kind of cover and the abundance of beetle grubs. Grubs are usually most abundant in pasture land. Abundance in other crop land is somewhat in the following order: corn, alfalfa, mixed hay, idle and fallow land, soybeans. Lands from which small grains have been removed, or land covered by forest, seldom have large grub populations.

In order to determine the relationship existing between land cover and grub populations, as well as the average number of grubs in all types of crops common in the demonstration area, extensive surveys were made in the fall of 1939. Ratios were then established for the abundance of beetles in pasture land as compared with abundance in other crops. Table 1 gives the ratios or the relationship between the number of grubs in crops, compared with pasture. These ratios were used to calculate the total quantity of beetles produced in each crop in the entire area and on individual farms.

Census figures on land utilization were used to estimate the number of beetles produced in the trapped area. The number produced on individual farms was calculated on the basis of actual surveys of land use on the farm. Table 2 illustrates method of calculation.

RESULTS WITH DISCUSSION.—After analysis and weighing, it was determined by the use of ratios that each square foot of land in the demonstration area, woodland included, contained an average of 4.51 grubs in the spring of 1938. This would produce an average of 59.6 quarts of beetles per acre for each and every acre in the area. The average number of beetles a trap will catch daily is hard to determine. The regularity with which the traps are emptied, the number of traps used in a given area, the location of the traps, and the length of time they are used, are important factors. Individual farmers had a daily average of from 1 to 3.5 quarts per trap, or a seasonal average of from 50 to 197 quarts. One man averaged 4.4 quarts daily for a period of 27 days. In 1939, 15 experimental traps in the demonstrational area averaged 1.01 quarts daily for a period of 34 days. In 1938 the 5,338 farm traps in the demonstrational area averaged 0.51 quart of beetles for each day they were operated.

In large scale operations it would seem fair and conservative to assume that if traps were distributed at the rate of one to each acre and properly operated, each trap would catch, during a 51-day beetle season which is normally from June 25 to August 15, an average of 0.51 quart of beetles per day, or a total of 26 quarts. If this could be accomplished the traps

**Table 2.—Illustrating method of calculating the total number of Japanese beetles produced on individual farms.**

| Crop | Total Number of Beetles Produced—D. O. Hanes' Farm | | | |
|---|---|---|---|---|
| | Ratio grub population in pasture land to other land | Based on pasture, averaging 9.3 grubs per square foot. Beetles produced in crops calculated from ratio of grubs in pasture to crops | | |
| | | No. quarts of beetles per acre | Number of acres | Total quarts of beetles produced |
| Pasture | 1.00000 | 122 | 15 | 1,831 |
| Corn | 0.62142 | 76.3 | 10 | 764 |
| Wheat | 0.06428 | 7.9 | 14.1 | 112 |
| Barley | 0.05000 | 6.2 | 17.2 | 108 |
| Mixed hay | 0.57857 | 71.1 | 7.3 | 520 |
| Woodlot | 0.01428 | 1.7 | 1.4 | 2 |
| Total | | | 65.0 | 3,337 |
| Quarts of beetles trapped | | | | 1,795 |
| Per cent of beetles trapped | | | | 53.6 |

would catch 43.3 per cent of the beetles produced.

In actual practice such efficiency probably could not be obtained throughout any large area due to differences in operation. It is interesting to examine the accomplishments in the Maryland demonstration. During the trapping season 178 property owners cooperated to the extent quantity of beetles equivalent to, or in excess of, 40 per cent of the total produced on their property. Several individuals with small farms, or lots, caught more than 100 per cent of the estimated total produced on their property.

Once beetles emerge it may be argued correctly that the population is not stable, and that there is general movement of

Table 3.—The efficiency of traps for controlling Japanese beetles on individual farms.

| Name of Cooperator | Acres in Farm | Traps Operated | Quarts Beetles Trapped | Trapping Results: Based on an ave. of 4.5 grubs per sq. ft. or 59.5 qts. of beetles per acre for demonstrational area. Total Quarts of Beetles Produced | % Beetles Trapped | Actual Beetles Produced (farm survey estimates) Total Quarts of Beetles Produced | % Beetles Trapped |
|---|---|---|---|---|---|---|---|
| Biddle, Andrew | 1 | 1 | 60 | 59.5 | 100.2 | | |
| Barnett, Chas. | 1 | 1 | 73 | 59.5 | 124.3 | | |
| Foster, N. F. | 1 | 4 | 66 | 59 | 111.8 | | |
| Todd, John | 1.25 | 2 | 43 | 74 | 58.1 | | |
| Schaible, John | 2.5 | 6 | 108 | 149 | 72.5 | | |
| Sempler, George | 4 | 1 | 120 | 238 | 50.4 | | |
| Ganzmann, C. | 10 | 6 | 284 | 595 | 112.2 | | |
| Gallaher, J. E. | 10 | 10 | 256 | 596 | 42.95 | | |
| Galyen, Glenn | 30 | 25 | 718 | 1,785 | 40.2 | | |
| Biddle, H. M. | 40 | 40 | 2,220 | 2,380 | 93.2 | 4,549 | 46.6 |
| Simpers, Charles | 45 | 40 | 2,844 | 2,677 | 106.3 | 4,670 | 60.9 |
| Robertson, J. W. | 60 | 60 | 1,598 | 3,570 | 44.7 | 6,100 | 26.2 |
| Hanes, D. O. | 65 | 65 | 1,795 | 3,867 | 46.4 | 3,342 | 53.6 |
| Seeman, John | 80 | 76 | 2,040 | 4,760 | 42.8 | | |
| Feucht, Carl | 90 | 90 | 2,444 | 5,355 | 45.6 | 12,042 | 20.3 |
| McIntire, Henry | 115 | 45 | 2,043 | 6,842 | 29.8 | | |
| Oniczuk, Andrew | 122 | 100 | 10,476 | 7,259 | 144.3 | 6,784 | 154.4 |
| Wood, J. F. | 129 | 130 | 3,434 | 7,675 | 44.7 | | |
| Bacchus, T. W. | 150 | 100 | 3,100 | 8,925 | 34.7 | 9,648 | 32.1 |
| Spry, Julian | 280 | 277 | 4,031 | 16,660 | 24.2 | 11,674 | 34.5 |
| Total | 1,366.75 | 1,209 | 41,187 | 81,330 | 50.6 | 58,809 | 48.4 |

of using 5,338 traps on 6,749.5 acres of land. By using census figures to determine the acreages and kinds of crops grown on the trapped farms, it was calculated that these properties produced 396,833 quarts of beetles, of which 119,029 quarts, or 30.1 per cent were trapped. In an endeavor to check for any error that might arise from the use of census figures, 32 farms, taken at random, involving 3,870 acres of land were surveyed in detail. These farms produced an estimated 228,431 quarts of beetles, of which 67,774 quarts, or 29.6 per cent were caught.

A study of the results obtained by individual farmers shows that the above figures are not indicative, necessarily, of what may be expected from efficiently operated traps. Many farmers caught a beetles between farms. In an endeavor to correct for migration, it was assumed that the beetles, in their movement, would distribute themselves rather evenly over the entire area, particularly where specialized farming does not exist. Calculations on this basis showed that individual farmers caught from 40 to over 100 per cent of the beetles that would logically forage on their farms. An analysis of 20 farms selected at random showed that an average of 50.6 per cent of the beetles were caught. Table 3 gives the results of calculations showing the efficiency of traps for catching Japanese beetles on individual farms.

VALUE OF TRAPS.—It is almost impossible to check accurately the value of traps in protecting crops. There is no technique for determining the loss that would have

occurred had traps not been used. Therefore, the question "Does trapping pay?" must be decided from experience, by those who use traps. Many Maryland farmers are convinced that it does pay to use traps. Field observations during the past two years indicate that traps lessen damage by reducing the number of beetles in the crops and by delaying the movement of beetles from surrounding territory into the crops. In the case of corn, delaying for a period of forty-eight hours the movement of beetles, in numbers, into the crop may determine whether or not the corn shall be poorly or adequately pollinated. Many careful and observant growers report that traps are useful in delaying the entrance of beetles into and lessening damage after they have entered, such crops as corn, asparagus, and soybeans. In one experiment this past summer, 1,416 quarts of beetles were caught with 100 traps in 25 acres of asparagus, in nineteen days, thereby reducing the beetles to a number no longer economically important.

The cost of traps, versus the value received from them, might be illustrated on the following basis: L. H. Worthley reported that in heavily infested areas the average loss in field corn from Japanese beetle damage was $5.00 per acre. This is conservative for the heavily infested areas in Maryland. If one trap to the acre will prevent 30 per cent of this loss, the increased yield in corn will have a value of $1.50. A twenty-eight cent trap should last for two years. Therefore, the cost of the trap, plus seven cents a year for bait and twenty-five cents a year for labor operating the trap, would make the trapping operations cost 49 cents per acre. This would leave a profit of $1.01 per acre. Very few farmers employ extra labor for operating traps; the labor already on the farm is used. Therefore, in such cases the actual saving would be $1.26 per acre. The value of traps in protecting other crops should be in proportion to the value of the crop and the potential damage from the beetle.

SUMMARY.—Data collected in a large scale trapping demonstration in Maryland show that 5,338 traps on 6,749 acres of land caught approximately 30 per cent of the beetles produced in the area. Results obtained on individual farms indicate that a much higher efficiency may be expected if one trap to the acre is used and the trap is operated efficiently. Many individual farmers caught from 40 per cent to over 100 per cent of the quantity of beetles produced on their property. It was impossible to check accurately the value of traps in protecting crops but both field observations and opinions of farmers using traps indicate that traps can be profitably used to lessen crop losses.

The results obtained also show that traps are not efficient to the extent of fully protecting crops from Japanese beetle damage but there is every indication that they have a place in a control program, not only as a supplementary control measure, but under certain conditions, as a direct measure.—11-16-39.

# Relation of Color to the Effectiveness of Japanese Beetle Traps

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Since 1931 a trap painted green and white has been considered to be the most effective for capturing the Japanese beetle (*Popillia japonica* Newman) (Metzger 1932, 1934; Van Leeuwen and Metzger 1930; and Van Leeuwen and Van der Meulen 1931). Today there are thousands of Japanese beetle traps on the market which range in color from light to dark green and from yellowish to bluish green. Many questions have been raised as to the proper shade of green and the importance of having the different parts painted green or white.

In view of this situation, all the data on which the original recommendation was made were carefully reexamined. It was evident, in the light of present

[1] The writers are indebted to E. G. Brewer for supplying scouting traps and bait for this investigation. They also wish to acknowledge the assistance of the subprofessional workers at the Japanese beetle laboratory, especially H. W. Strabel, in conducting the routine phases of this work.

knowledge of the design of field experiments and the analysis of data, that much of the early experimental work had been carried out in such a manner that proper compensation was not made for the variability in the density of the beetle population. Most of the results were influenced by this important, uncontrolled factor. The only definite evidence was that, for certain shades of green, a green-and-white trap was superior to a trap painted all green, green and aluminum, or aluminum. This information was inadequate to answer the many questions regarding the color of the traps. An investigation was accordingly conducted during the summer of 1939 to establish more definitely the most effective color for the trap.

TRAPS AND BAIT.—The bait was composed of 10 parts of geraniol and 1 part of eugenol by volume and was dispensed by means of a bottle and wick. The trap covered by U. S. Patent 1,968,953, painted with the recommended green and white, was used as a standard. The 1939 model of the scouting trap was used for experimental purposes. This trap was modified only to the extent of painting it the desired color and replacing the beetle receptacle with a larger can so that it could operate more effectively in an area with a denser population than that for which it was designed. These two types of traps were equivalent in that the effective area of the wings of the baffles and the quantity of bait given off by their dispensers were about the same; they differed in the size and slope of the funnels and in the type and size of their receptacles for holding the beetles.

The traps were painted with "automotive type" lacquers, as these paints were known to have a high luster and to change very little in shade upon exposure to the weather. Some of the colors were applied in the form obtained from the manufacturer and some were mixed in various proportions to obtain variations in shades. The attempt to identify these colors by reference to a standard color dictionary was not successful because most of the colors were beyond the scope of the charts. In order that other investigators may be able to identify these colors more definitely, the manufacturer's numbers[2] and the proportions used in preparing the mixtures are given in table 1.

METHOD OF TESTING.—The traps were arranged in the field in 10 Latin squares containing 25 units of which 20 were experimental traps and 5 were standard traps. Each trap was hung about 4 feet above the ground, on a metal rod, and was placed 20 feet away from the adjacent traps in the row and column. The exposed sides of these squares were lined with "barrier" traps of the same type as the standard to prevent the outer experimental traps from catching much larger

**Table 1.—Colors used in painting Japanese beetle traps.**

| TRAP NO. | COLOR | MANUFACTURER'S NO. | PROPORTIONS BY VOLUME IN MIXTURE |
|---|---|---|---|
| 1 | Aluminum | 45 | — |
| 2 | White | 83,508 | — |
| 3 | Light yellow | 83,508<br>83,112 | 1<br>1 |
| 4 | Yellow | 83,112 | — |
| 5 | Very yellowish green | 83,112<br>83,106 | 20<br>1 |
| 6 | Yellowish green | 83,112<br>83,106 | 7<br>1 |
| 7 | Slightly yellowish green | 83,112<br>83,106 | 2<br>1 |
| 8 | Very slightly yellowish green | 83,112<br>83,106 | 1<br>2 |
| 9 | Medium green | 83,106 | — |
| 10 | Slightly bluish green | 83,106<br>83,107 | 3<br>1 |
| 11 | Bluish green | 83,106<br>83,107 | 1<br>1 |
| 12 | Dark bluish green | 83,107 | — |
| 13 | Light medium green* | 83,524 | — |
| 57 | Red | 83,104 | — |
| 58 | Dark blue | 83,108 | — |
| 59 | Reddish orange | 83,112<br>83,104 | 2<br>1 |
| 60 | Orange | 83,101 | — |
| 61 | Light blue | 83,508<br>83,108 | 2<br>1 |
| 62 | Pink | 83,508<br>83,104 | 2<br>1 |
| Standard | Green and white | 83,524<br>83,508 | —<br>— |

* The color used in the green portion of the standard trap.

[2] The aluminum lacquer was obtained from the Dietzler Color Company, Detroit, Mich.; the other lacquers were obtained from the E. I. DuPont de Nemours Company, Philadelphia, Pa. The designation of these materials by manufacturer's number is for the identification of the color and does not imply that the products of these companies are recommended in preference to those available from other sources.

numbers of beetles than those near the center of the squares. Experience during the past two years has shown that this design of experiment is the best for eliminating a large part of the variation.

Some of these experiments were carried on for seven weeks—almost the entire period of beetle flight. Others were carried on for five weeks, being started July 14, after beetle flight had been in progress for two weeks but before beetle abundance had reached its height.

The beetles were collected from these traps three times each week throughout the season, extending from June 29 to August 17, except during the height of the season when it was necessary to make the collections more frequently. A record was made of these collections and from this the weekly capture by each trap was determined.

ANALYSIS OF DATA.—During the season 188,855 beetles were captured in the 10 Latin squares and at least an equal number was taken in the "barrier" traps. In the number of beetles taken there was considerable variation in the different blocks during any period and in the same block from week to week during the season. The minimum caught by an experimental unit in a week was 246 beetles and the maximum 12,936 beetles. When the relative standard errors of the capture per trap in each block were determined for weekly periods, no correlation was found between the number captured and the relative error. The minimum relative error of the general block mean was 1.90 per cent, the maximum was 6.74 per cent, and the seasonal average was 3.34 per cent. It was found that the relative experimental error was very low and remained practically constant in the various blocks during the season.

An analysis was made of the variance in the number of beetles captured in each block for each week of the season. These analyses showed that the variation in the number of beetles from row to row and from column to column of each block was either significant or non-significant, but the greatest variation in the block was brought about by the modification of the color of the trap.

When a large number of comparisons are to be made, it is the general practice to design the experiment so that all units occur in a large Latin square or in a number of small squares in order that all units which are to be compared may occur in the same block. In these experiments the size of the experimental block had to be limited to 25 units to avoid introducing additional error by the increase in the heterogeneity of the distribution of beetles that would occur in a larger block. It was impractical to set up the large number of small squares necessary in making all comparisons directly. As the standard trap was placed in each block and as the relative standard error was practically constant, however, it seems entirely proper to adjust for the differences in the level of the population from block to block and from week to week by expressing the weekly capture by an experimental trap as an index number, computed by dividing the beetles in each experimental trap by the number captured in the standard trap in the same block and multiplying the quotient by 100. Index numbers of the effectiveness of each experimental trap were prepared weekly throughout the season. Analyses of variance of the sets of comparisons shown in the following tables indicate that differences of approximately 20 points in the seasonal index numbers are needed for significance at odds of 19 to 1.

The question still remained whether the number of beetles captured by a trap was not greatly influenced by the colors of the competing traps in the Latin square. In order to obtain information on the importance of this factor, each color was placed in different blocks with different competitors, as indicated in the following tabulation:

1. **Aluminum** with:—
   (a) White, light yellow, yellow
   (b) White and two shades of green

2. **White** with:—
   (a) Aluminum, light yellow, yellow
   (b) Aluminum and two shades of green
   (c) Yellow, red, dark blue

3. **Yellow** with:—
   (a) Aluminum, white, light yellow
   (b) White, red, dark blue

4. **Very yellowish green** with:—
   (a) Three shades of yellowish greens
   (b) Light yellow and two bluish greens

5. **Medium green** with:—
   (a) Three bluish greens
   (b) Aluminum, white, and light medium green

**Table 2.—The effect of the primary colors, white and aluminum, on the number of beetles captured in Japanese beetle traps.**

| TRAP NO. | COLOR | INDEX OF EFFECTIVENESS | | | | | WEIGHTED SEASONAL AVERAGE |
|---|---|---|---|---|---|---|---|
| | | First Week | Second Week | Third Week | Fourth Week | Fifth Week | |
| 1 | Aluminum | 58 | 61 | 48 | 50 | 46 | 50.6 |
| 57 | Red | 58 | 88 | 94 | 79 | 111 | 78.4 |
| 58 | Dark blue | 74 | 98 | 97 | 88 | 107 | 88.6 |
| 2 | White | 106 | 101 | 91 | 89 | 101 | 97.0 |
| 4 | Yellow | 187 | 163 | 155 | 133 | 157 | 150.8 |

6. **Light medium green** with:—
   (a) Aluminum, white, medium green
   (b) Light yellow, very yellowish green, dark bluish green

7. **Dark bluish green** with:—
   (a) Medium green, and two bluish greens
   (b) Light yellow, very yellowish green, light medium green

When the effect of the color of the competitors on all these traps was considered, it was apparent that although the color of the competitors in a block had some influence on the rating of a trap it was a minor factor. There was no doubt that, after the differences in the level of the population had been adjusted, the most important factor governing the number of beetles captured was the color of the trap.

In studying the reaction of the beetles to traps it has been found that few beetles are attracted to unbaited traps or to traps baited with materials only slightly attractive. The general observation with traps painted different colors was that about the same number was attracted to each, but that with some of the colors more of the beetles avoided flying into the baffle. This suggests that a beetle is better able to discern and avoid obstacles painted with some colors than with other colors.

INFLUENCE OF THE PRIMARY COLORS AND WHITE AND ALUMINUM.—All parts of scouting traps were painted red, dark blue, yellow, white, and aluminum to determine the effect of these colors on the number of bettles captured as compared with the green-and-white standard traps. The weekly index of effectiveness and the weighted seasonal average for each trap are given in table 2.

It was apparent that the aluminum paint was much less effective than the standard, as only 50.6 per cent as many beetles were captured. This evaluation of the aluminum trap is in agreement with that given by Metzger in unpublished reports of randomized experiments conducted during 1934 and 1935.

The striking feature of these results is that traps painted yellow captured significantly more beetles than did those painted red, dark blue, or white. The weighted seasonal average of the yellow trap was 53.8 per cent better than its nearest competitor among the traps painted with one color and it was 50.8 per cent better than the green-and-white standard. Although the superiority of yellow over the other primary colors seemed apparent it was thought that the relative value of these colors could be more definitely established by studying the effect of the addition of the primary colors and white to other colors.

**Table 3.—The effect of adding red to other colors on the number of beetles captured in Japanese beetle traps.**

| TRAP NO. | COLOR | INDEX OF EFFECTIVENESS | | | | | WEIGHTED SEASONAL AVERAGE |
|---|---|---|---|---|---|---|---|
| | | First Week | Second Week | Third Week | Fourth Week | Fifth Week | |
| 2 | White | 106 | 101 | 91 | 89 | 101 | 97.0 |
| 62 | Pink | 51 | 45 | 57 | 52 | 85 | 53.0 |
| 4 | Yellow | 187 | 163 | 155 | 133 | 157 | 150.8 |
| 60 | Orange | 113 | 138 | 154 | 120 | 151 | 129.0 |
| 59 | Reddish orange | 90 | 120 | 114 | 99 | 142 | 106.1 |
| 57 | Red | 58 | 88 | 94 | 79 | 111 | 78.4 |

**Table 4.—The effect of adding blue to other colors on the number of beetles captured in Japanese beetle traps.**

| Trap No. | Color | Index of Effectiveness | | | | | Weighted Seasonal Average |
|---|---|---|---|---|---|---|---|
| | | First Week | Second Week | Third Week | Fourth Week | Fifth Week | |
| 2 | White | 106 | 101 | 91 | 89 | 101 | 97.0 |
| 61 | Light blue | 64 | 64 | 76 | 53 | 88 | 65.3 |
| 4 | Yellow | 187 | 163 | 155 | 133 | 157 | 150.8 |
| 9 | Medium green | 159 | 143 | 110 | 94 | 79 | 108.2 |
| 10 | Slightly bluish green | 156 | 128 | 120 | 88 | 78 | 107.9 |
| 11 | Bluish green | 122 | 114 | 112 | 86 | 80 | 98.5 |
| 12 | Dark bluish green | 113 | 99 | 87 | 74 | 79 | 82.9 |

EFFECT OF ADDING RED.—The effect of adding red to other colors was studied by comparing the results obtained with white, pink, yellow, orange, reddish orange, and red, and analyzing the variance in the weekly index numbers to determine the significance of the differences. These results are summarized in table 3. It was found that when red was added to white, yellow, orange, or reddish orange the effectiveness of these colors was significantly reduced.

EFFECT OF ADDING BLUE.—The effect of adding blue to other colors was studied by comparing the number of beetles captured by the white and light blue, and the yellow, medium green, slightly bluish green, bluish green and dark bluish green traps. These results are given in table 4. It was apparent that the addition of blue significantly reduced the effectiveness.

EFFECT OF ADDING WHITE.—The effect of adding white to other colors was studied by comparing the effectiveness of red and pink, yellow and light yellow, dark blue and light blue, medium green and light medium green traps. These results are given in table 5. It is evident that the addition of white significantly reduced the effectiveness of the other colors.

EFFECT OF ADDING YELLOW.—The effect of adding yellow to other colors was studied by comparing the results obtained with white, light yellow, and yellow; red, reddish orange, and orange; and dark blue, dark bluish green, bluish green, slightly bluish green, medium green, very slightly yellowish green, slightly yellowish green, yellowish green, and very yellowish green. These results are given in table 6.

There is no doubt that the addition of yellow to white and red very significantly increased the effectiveness of these colors. As previous investigators (3) had indicated that green was the most effective color for traps, considerable attention was given to the different shades of this color. It was found that there was a very defi-

**Table 5.—The effect of adding white to other colors on the number of beetles captured in Japanese beetle traps.**

| Trap No. | Color | Index of Effectiveness | | | | | Weighted Seasonal Average |
|---|---|---|---|---|---|---|---|
| | | First Week | Second Week | Third Week | Fourth Week | Fifth Week | |
| 57 | Red | 58 | 88 | 94 | 79 | 111 | 78.4 |
| 62 | Pink | 51 | 45 | 57 | 52 | 85 | 53.0 |
| 58 | Dark blue | 74 | 98 | 97 | 88 | 107 | 88.6 |
| 61 | Light blue | 64 | 64 | 76 | 53 | 88 | 65.2 |
| 4 | Yellow | 187 | 163 | 155 | 133 | 157 | 150.8 |
| 3 | Light yellow | 165 | 134 | 111 | 100 | 111 | 114.7 |
| 9 | Medium green | 159 | 143 | 110 | 94 | 79 | 108.2 |
| 13 | Light medium green* | 98 | 108 | 89 | 66 | 87 | 89.6 |

* The color used in the green portion of the standard trap.

nite trend for the effectiveness to increase as dark blue was changed progressively to bluish green, medium green, and yellowish green, although the differences in effectiveness as each step was taken were usually small and somewhat variable. The results did show definitely that a yellowish green trap was significantly better than a bluish green trap.

As a yellow trap was definitely superior to those painted any other color and as yellow was the only pigment which, when added to other colors, increased their effectiveness, it is evident that yellow is the most effective color for painting traps.

**Table 6.—The effect of adding yellow to other colors on the number of beetles captured in Japanese beetle traps.**

| Trap No. | Color | Index of Effectiveness | | | | | Weighted Seasonal Average |
|---|---|---|---|---|---|---|---|
| | | First Week | Second Week | Third Week | Fourth Week | Fifth Week | |
| 2 | White | 106 | 101 | 91 | 89 | 101 | 97.0 |
| 3 | Light yellow | 165 | 134 | 111 | 100 | 111 | 114.7 |
| 4 | Yellow | 187 | 163 | 155 | 133 | 157 | 150.8 |
| 57 | Red | 58 | 88 | 94 | 79 | 111 | 78.4 |
| 69 | Reddish orange | 90 | 120 | 114 | 99 | 142 | 106.1 |
| 60 | Orange | 113 | 138 | 154 | 120 | 151 | 129.0 |
| 58 | Dark blue | 74 | 98 | 97 | 88 | 107 | 88.6 |
| 12 | Dark bluish green | 113 | 99 | 87 | 74 | 79 | 82.9 |
| 11 | Bluish green | 122 | 114 | 112 | 86 | 80 | 98.5 |
| 10 | Slightly bluish green | 156 | 128 | 120 | 88 | 78 | 107.9 |
| 9 | Medium green | 159 | 143 | 110 | 94 | 79 | 108.2 |
| 8 | Very slightly yellowish green | 150 | 146 | 103 | 84 | 100 | 107.9 |
| 7 | Slightly yellowish green | 147 | 159 | 122 | 93 | 102 | 117.4 |
| 6 | Yellowish green | 140 | 144 | 112 | 81 | 108 | 108.6 |
| 5 | Very yellowish green | 158 | 150 | 109 | 89 | 106 | 112.4 |

EFFECTIVENESS OF GREEN AND WHITE TRAPS.—In 1931 Van Leeuwen & Van der Meulen (4) reported that green traps with the baffle and the inside of the funnel painted white caught more beetles than those entirely green. Unpublished reports by Metzger in 1932 and 1933 confirm this conclusion. In 1939 this work was repeated with the object of determining the accuracy of the previous conclusions, and of attempting to explain the increased effectiveness of the green and white traps over the green traps, if the results confirmed earlier work. All parts of some of the traps were painted dark bluish green, light medium green, and white. Then one or more parts of the green traps were painted white and one or more parts of the white traps were painted dark bluish green or light medium green. The details of the color of the different parts of the traps and their relative effectiveness in capturing beetles are given in table 7.

The analyses of the variance in the ratings showed that very significant changes in effectiveness occurred with the modification of the color of the different parts. There was no doubt that a trap with the baffle and inside of the funnel painted white and the outside of the funnel and the can painted green, as has been recommended for the scouting traps, was significantly more effective than an entirely green trap in capturing beetles. However, the results demonstrated that when the baffle, cone and inside of the funnel of a green trap were painted white, the performance of the trap was very similar to that of one painted entirely white; when these parts of a white trap were painted dark bluish green or light medium green the performance of the trap was of the order of that of traps painted entirely with these shades of green. In order to obtain further information on the effectiveness of the green and white traps, the scouting traps with white on the baffle and inside the funnel and with the outside of the funnel and can painted light medium green, medium green, and dark bluish green were compared with the standard trap which was painted in the same manner with white

and light medium green. It was not possible to demonstrate statistically any significant difference in the performance of the standard and that of the scouting traps painted in this manner with different shades of green. It was apparent that the shade of green on the *outside* of the funnel and can was not an important factor.

These experiments demonstrated conclusively that the color of the baffle and the inside of the funnel is the most important factor governing the effectiveness of a trap in capturing the beetles which are attracted to it. The color of the outside of the funnel and the can appears to be of minor importance. As the evidence shows clearly that the present green and white traps are functioning practically as white traps, there seems to be no advantage in continuing the dual color scheme on the traps.

**Table 7.—The effectiveness of Japanese beetle traps painted green and white in capturing beetles.**

| Trap No. | Color of Parts | | | | Index of Effectiveness | | | | | | | Weighted Seasonal Average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Baffle Cone | Funnel | | Can | First Week | Second Week | Third Week | Fourth Week | Fifth Week | Sixth Week | Seventh Week | |
| | | Inside | Outside | | | | | | | | | |
| 12 | Dark bluish green | Dark bluish green | Dark bluish green | Dark bluish green | 113 | 99 | 87 | 74 | 79 | 59 | 86 | 80.0 |
| 16 | Dark bluish green | Dark bluish green | White | White | 79 | 86 | 91 | 71 | 83 | 51 | 78 | 76.4 |
| 17 | Dark bluish green | White | White | White | 76 | 84 | 100 | 78 | 80 | 46 | 75 | 77.6 |
| 13 | Light medium green† | Light medium green | Light medium green | Light medium green | 98 | 108 | 89 | 66 | 87 | 57 | 74 | 81.9 |
| 20 | Light medium green | Light medium green | White | White | 78 | 80 | 81 | 72 | 71 | 61 | 74 | 73.1 |
| 21 | Light medium green | White | White | White | 84 | 98 | 82 | 73 | 73 | 58 | 65 | 75.5 |
| 15 | White | Dark bluish green | White | White | 73 | 77 | 87 | 80 | 79 | 56 | 82 | 76.0 |
| 14 | White | Dark bluish green | Dark bluish green | Dark bluish green | 98 | 108 | 97 | 87 | 91 | 69 | 81 | 88.6 |
| 23 | White | White | Dark bluish green | Dark bluish green | 93 | 112 | 102 | 95 | 97 | 94 | 78 | 97.1 |
| 19 | White | Light medium green | White | White | 76 | 102 | 92 | 80 | 81 | 64 | 66 | 81.5 |
| 18 | White | Light medium green | Light medium green | Light medium green | 109 | 107 | 110 | 94 | 101 | 75 | 85 | 96.6 |
| 22 | White | White | Light medium green | Light medium green | 104 | 123 | 106 | 118 | 104 | 95 | 81 | 106.4 |
| 24 | White | White | Medium green | Medium green | 97 | 102 | 104 | 103 | 97 | 77 | 70 | 94.9 |
| 8* | White | White | Light medium green | — | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100.0 |
| 2 | White | White | White | White | 106 | 101 | 91 | 89 | 101 | 80 | 81 | 96.3 |

* Standard trap; the other traps were scouting traps.
† Used in the green portion of the standard trap.

SUMMARY.—In an investigation conducted during the summer of 1939, traps painted entirely yellow were found to be definitely superior in effectiveness to those painted aluminum, white, light yellow, light blue, dark blue, pink, red, orange, reddish orange, and green varying in shade from light to dark and from yellowish to bluish. The evidence this season showed that a scouting trap painted with a yellow to which no other pigment was added captured 50.8 per cent more beetles than the green and white standard trap which has been used extensively in recent years. The addition of yellow to other pigments always enhanced their effectiveness. It follows logically that to secure the greatest capture of the beetles attracted, the trap should be painted with a primary yellow.

It was demonstrated conclusively that a trap painted green and white is more effective than a green trap in capturing the Japanese beetles attracted to it. It was found, however, that when the baffle and the inside of the funnel of a green trap were painted white, the trap functioned as a white trap; when these parts of a white trap were painted green, the trap performed as a green trap. The shade of green on the outside of the funnel and on the beetle receptacle was a minor factor. As the color of the baffle and the inside of the funnel govern the effectiveness of the trap, there seems to be no necessity for using a dual color scheme on the trap.

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# Properties of Two Samples of Commercial Geraniol Used in Japanese Beetle Baits

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Geraniol has been used for a number of years as the principal component of the bait used in trapping the Japanese beetle. In 1935 Metzger and Maines proposed the following specifications, which are still in force, for commercial geraniol to be used for this purpose:

"Specific gravity at 20° C.—0.875–0.895.
"Solubility in 70-percent ethyl alcohol—1 part in not more than 2 parts of alcohol.
"Aldehydes as citronellal—Not more than 3.5 percent.
"Esters as geranyl acetate—Not more than 15 percent.
"Total free alcohols as citronellol and geraniol—More than 70 percent.
"Odor—Absence of any significant indication of added materials.
"Boiling range—Not more than 5 percent boiling under 225° C. or more than 18 percent boiling over 245° (760 mm pressure)."

The specific gravities quoted (assuming reference to water at 15 degrees C.) are equivalent to densities of 0.874 to 0.894 gr. per cc. The temperature of the solubility test is not specified. These specifications were not designed to give a pure geraniol but rather a commercial grade believed from the results of numerous tests to be most attractive to the beetle. More recently, however, investigators at the Japanese beetle laboratory have found variations in the attractiveness of commercial geraniols meeting these specifications, indicating the desirability of a renewed study of these baits. At their request the writers have undertaken a study of the chemical phases of this problem.

In the present work the properties of two samples of commercial geraniol have been studied. Both samples, as found by analyses previously made at the Japanese beetle laboratory and shown by the results in table 1, meet the requirements given by Metzger and Maines. Other properties of the samples are given. For comparison, the properties are also given of a sample of pure geraniol made by a standard laboratory method for preparing pure geraniol. It is based on the fact

**Table 1.—Physical and chemical properties of two samples of commercial geraniol and a sample of pure geraniol.**

| Sample | Alcohols as Geraniol | Esters as Geranyl Acetate | Aldehydes as Citronellal | Boiling Range* (Degrees C.) at 760 mm. | Density (Gr. per cc.) at 20° C. | Density (Gr. per cc.) at 27° C. | Viscosity at 27° C., Poises | Refractive Index $n_D^{20}$ | Specific Optical Rotation† $[\alpha]_D^{20}$ |
|---|---|---|---|---|---|---|---|---|---|
| Geraniol‡ A | 86.8%* | 13.5% | 1.8%* | Initial—224.4<br>0.2%—225<br>5%—226.9<br>82%—232.0<br>Dry—235.5 | 0.878 | 0.872 | 0.048 | 1.467 | −0.1 |
| Geraniol‡ B | 74.5% | 11.5% | 1.0% | Initial—224.2<br>Trace—225<br>5%—229.0<br>82%—243.7<br>84%—245<br>Dry—258.2 | 0.891 | 0.888 | 0.060 | 1.474 | +0.3 |
| Pure Geraniol | — | — | — | — | 0.879 | 0.873 | 0.061 | 1.473 | +0.2 |

* These values were determined by L. Koblitsky of the Divison of Insecticide Investigations at Moorestown, N. J.
† The significance of values for optical rotation of 0.2 degree or less, considering the instrument used, is questionable.
‡ Solubility in 70 per cent alcohol and odor of both samples were considered satisfactory.

Table 2.—Fractionation of geraniol A and properties of fractions.

| Fraction No. | Volume Proportion | Approximate Boiling Point (C.) | Density at 27 Degrees C. (Gr. per cc.) | Viscosity at 27 Degrees C. (Poises) | Refractive Index $\eta_D^{25}$ | Specific Optical Rotation* $[\alpha]_D^{20}$ |
|---|---|---|---|---|---|---|
| 1 | 22.1% | 84° at 3 mm. | 0.871 | 0.048 | 1.467 | −0.4 |
| 2 | 32.5 | 84° at 2.5 mm. | 0.870 | 0.049 | 1.467 | −0.1 |
| 3 | 27.5 | 85° at 2.5 mm. | 0.871 | 0.048 | 1.467 | +0.1 |
| 4 | 8.7 | 86° at 2.5 mm. | 0.873 | 0.047 | 1.468 | +0.2 |
| 5 | 6.2 | 90° at 2.5 mm. | 0.876 | 0.047 | 1.469 | +0.2 |
| 6 | 1.6 | — | 0.884 | 0.045 | 1.471 | +0.5 |
| Total distillate | 98.6 | | | | | |

* The significance of values for optical rotation of 0.2 degree or less, considering the instrument used, is questionable.

that geraniol combines with calcium chloride to form a solid compound from which it may later be liberated by treatment with water, whereas other constituents of the oil do not react in this way. The method of separation is not quantitative. In preparing the pure geraniol sample two successive calcium chloride treatments of commercial geraniol A were used and this was followed by distillation at reduced pressure. The sample distilled at constant temperature and its boiling point determined in a micro apparatus was 229 degrees C. at 767.8 mm. Pure geraniol should be optically inactive, but the sample prepared as described had a very slight dextro-rotation. Its other properties, agreed well with values in the literature.

To obtain further insight into the composition of the two commercial samples, both were subjected to fractional distillation. This was done under greatly diminished pressure so that at no time during the distillation did the temperature of the residue in the still exceed 160 degrees C. In the case of geraniol A a 45-centimeter Widmer column was used. The results and the properties of the fractions obtained are shown in table 2. It will be noted that much of the material distills at almost constant temperature and that the properties of most of the fractions are the same. Although fractions 2 and 3 might be considered from their properties to be almost pure geraniol, they gave only about 50 per cent and 60 per cent geraniol on treatment with

Table 3.—Fractionation of geraniol B and properties of fractions.

| Fraction No. | Volume Proportion | Approximate Boiling Point (C.) | Density at 27 Degrees C. (Gr. per cc.) | Viscosity at 27 Degrees C. (Poises) | Refractive Index $\eta_D^{25}$ | Specific Optical Rotation $[\alpha]_D^{20}$ |
|---|---|---|---|---|---|---|
| 1+2 | 2.7% | 98° at 5 mm. | 0.873 | 0.055 | 1.459 | −1.4 |
| 3+4 | 3.4 | 98° at 5 mm. | 0.862 | 0.057 | 1.459 | −0.5 |
| 5 | 6.5 | 102° at 5 mm. | 0.864 | 0.056 | 1.462 | +0.3 |
| 6 | 10.1 | 96° at 4 mm. | 0.868 | 0.053 | 1.465 | +0.4 |
| 7 | 11.5 | 92.5° at 3 mm. | 0.874 | 0.051 | 1.469 | +0.4 |
| 8 | 15.7 | 79° at 1 mm. | 0.877 | 0.051 | 1.471 | +0.7 |
| 9 | 12.6 | 80° at 1 mm. | 0.878 | 0.050 | 1.472 | +0.7 |
| 10 | 11.0 | 85° at 2 mm. | 0.888 | 0.046 | 1.475 | +2.7 |
| 11 | 4.1 | 87° at 2 mm. | 0.903 | 0.041 | 1.479 | +3.6 |
| 12 | 2.1 | 95° at 2 mm. | 0.934 | 0.048 | 1.492 | +15.3 |
| 13 | 2.6 | 101° at 2 mm. | 0.927 | 0.12 | 1.498 | +33.7 |
| 14 | 2.5 | 108° at 2 mm. | 0.931 | 0.35 | 1.497 | +17.9 |
| 15 | 2.3 | 116° at 2 mm. | 0.940 | * | 1.495 | −4.8 |
| 16 | 1.9 | 123° at 2 mm. | 0.947 | * | 1.497 | −7.1 |
| Total distillate | 89.0 | | | | | |

* Too viscous to be measured in the apparatus used.

calcium chloride. An appreciable proportion of laevo-rotatory material shows up in the lowest-boiling fraction while a dextro-rotatory material appears in the highest-boiling one, but these are so balanced in the original as to give a material of practically no optical activity.

Geraniol B was subjected to fractional distillation using a 32 stage column. The larger distillation apparatus was used in the case of this material because a larger sample was taken. Because the pressure could not be kept constant, it was necessary to take fractions more or less arbitrarily and their physical properties were used as an indication of fractions of approximately the same composition. The results are shown in table 3. Fractions 1 and 2, as well as 3 and 4, were combined immediately after distillation. The wide spread of physical properties of the fractions as compared with those of geraniol A is immediately apparent. Fractions 5 to 9, inclusive, are of approximately the same composition and probably contain most of the geraniol present in the sample. Together they constitute 55.5 per cent by weight of the sample. In the upper fractions density and refractive index values are markedly higher than those for pure geraniol, but the sample is so blended as to make the refractive index approximately that of pure geraniol and the density only slightly higher (Table 1). The last three fractions were very viscous and all three became solid on standing at minus 6 degrees C. Optical rotation was perhaps the most interesting property in furnishing an indication of the relative composition of the fractions, and the wide spread of values is especially noticeable. Fraction 13 evidently contains a strongly dextro-rotatory constituent. The optical rotatory power in conjunction with the amount of each fraction would indicate that the entire sample had a specific rotation of about plus 2 degrees, but it has only a slight dextro-rotation (Table 1). The residue in the still was probably sufficiently laevo-rotatory to account for this, but measurements were not made because of the deep color and possible decomposition of the residue.

Thus geraniol A, which is well within the specifications for use in a Japanese beetle bait, probably consists of relatively few components, whereas geraniol B, which is just within the limits in some respects, appears to consist of a number of components with widely different physical properties. Determination of the composition of geraniol B is now under way.

The detailed results of entomological tests on these two materials will be reported by the Division of Fruit Insect Investigations on the completion of the work. The preliminary results, however, have indicated wide enough differences among commercial geraniols to warrant a more detailed investigation of the subject, leading to the development of specifications that will give a product of still greater attractiveness to the beetles. From the standpoint of obtaining a more definite product a new set of requirements should, perhaps, include not only the properties previously specified but others, such as viscosity and optical rotation, as well as chemical determinations sufficient to fix the composition of the material.—11-8-39.

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# Toxicities to the Housefly of Smoke from Derris and Pyrethrum

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The action of derris as a contact and as a stomach insecticide has been extensively investigated, but its action as a fumigant in the form of smoke has been studied only in a preliminary manner. McIndoo (1924) tested the smoke from derris, cubé, and pyrethrum qualitatively, by burning small amounts in a closed

space, and found that aphids, ladybeetles, and some other species of insects were killed by all these materials. The burning of tobacco, with or without added nicotine, has become a standard practice and is quite successful in the control of certain insects, such as aphids. For a time the smoke from burning pyrethrum was recommended as a fumigant, but the generally poor results have led to other methods of application.

Preliminary tests by the writers on the effect of smoke from burning derris on the housefly (*Musca domestica* L.) appeared so promising that it was decided to carry the investigation further. Tests on the toxicity of this smoke compared with that from pyrethrum burned in the same manner are reported in this paper.

**Table 1.—Toxicity of the smoke from derris and pyrethrum when tested against housefly.**

| Material* | Concentrations, Oz. per 1000 Cu. Ft. | Average Mortality in 72 Hours, Per Cent |
|---|---|---|
| Derris mixture | 4 | 95 ± 1.7 |
| same | 2 | 93 ± 0.5 |
| same | 0.5 | 32 ± 7.2 |
| Pyrethrum mixture | 12 | 74 ± 6.8 |
| same | 8 | 32 ± 1.8 |
| same | 4 | 14 ± 2.8 |
| Checks: | | |
| Derris marc | 4 | 9 |
| Pyrethrum marc | 12 | 10 |

* These mixtures contained 50 per cent of the material, 30 per cent of cornstalks, and 20 per cent of sodium nitrate.

MATERIALS AND METHODS.—The derris used for these experiments was from a finely ground commercial sample containing 4.9 per cent of rotenone and 17.1 per cent of total chloroform extractives. It was composed mainly of *Derris malaccensis*, since it contained large amounts of toxicarol. The pyrethrum was from a finely ground commercial sample containing 0.76 per cent of total pyrethrins. This is slightly low for Japanese pyrethrum, for it usually contains about 0.9 per cent.

In order to burn these insecticides, a mixture composed of 50 per cent derris or pyrethrum, 30 per cent coarsely ground cornstalks, and 20 per cent technical sodium nitrate was prepared. The nitrate was added in water solution, and the mixture was dried at 50° C. in a steam cabinet until the moisture content was less than 1 per cent. The cornstalks were added to improve the burning properties of the mixture,[1] as finely ground commercial derris powders cannot be satisfactorily burned even in the presence of nitrates. Similar mixtures in which derris or pyrethrum marc was substituted for the unextracted insecticide were also prepared for use as controls to determine the effect of the smoke alone. All these mixtures contained nearly the minimum amount of nitrates to give an even, rapid rate of burning without flame.

For the toxicity tests trapped wild flies were used, and a special effort was made to obtain a representative population. They were fed and held for one day before the tests were made. One or two cages at a time containing about 300 flies each were exposed to the smoke in a Peet-Grady chamber for one hour at 25° to 29° C. The cages were in the form of about 10-inch cubes having screen wire on two opposite sides and the top. A complete run, consisting of tests at three dosages each of derris and pyrethrum and a test on each of the marcs, was made in a day. Except for some of the controls, these tests were repeated on two following days. Five tests, using a total of about 1,500 flies, were made to obtain the average mortality at each dosage.

In making the exposure derris was burned in open dishes of suitable size at rates of 0.5, 2.0, and 4.0 ounces per 1000 cubic feet. A fan was used to distribute the smoke for about a minute after the material had completely burned. Pyre-

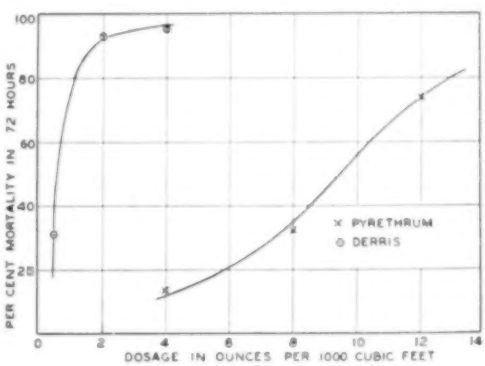


FIG. 1.—Relation of dosage to mortality.

[1] It has since been found that coarsely ground derris containing as high as 27 per cent of extractives can be burned in the presence of nitrates without the addition of extra organic material.

thrum in dosages of 4.0, 8.0, and 12.0 ounces per 1000 cubic feet was burned in the same manner. The derris and pyrethrum mares were used only at dosages of 4.0 and 12.0 ounces, respectively. All dosages refer to the amount of derris or pyrethrum in the mixtures.

After exposure the flies were fed and left in the same cages. Counts were made in the usual manner after 72 hours. In two tests unexposed flies were kept for 72 hours in cages that had been exposed to the highest dosage of derris to determine if there was any residual effect from smoke.

RESULTS.—The results of these experiments are shown in table 1 and illustrated graphically in figure 1. It is obvious that derris applied in this manner is much more toxic to the housefly than is pyrethrum. If judged by the dosage required to kill 50 per cent it is more than ten times as toxic with these two samples, and even with a better sample of pyrethrum the derris would be much more toxic. In preparing these data the average kill for each concentration was used. One material is so much more toxic than the other that a complete statistical treatment was deemed unnecessary. The effect of the smoke alone was slight, and according to general practice it was disregarded in the preparation of the curves. The mortality of the unexposed flies in the exposed cages was only 6 per cent, showing that there was little or no residual effect from the smoke.

Flies exposed to the smoke from derris are definitely affected even at the low concentrations used, but the knock-down is not complete even at high concentrations. After sufficient exposure they are left in a moribund condition from which they never recover. Pyrethrum smoke, on the other hand, causes complete knock-down in about 10 minutes even in the low concentrations, but after a few hours a large proportion of the flies completely recover. Even the pyrethrum mare gave a good knock-down, but the recovery was very rapid.

SUPPLEMENTARY TESTS.—In tests with the American cockroach (*Periplaneta americana* L.) pyrethrum at the high concentrations killed about the same proportions of roaches as of flies but derris had little or no effect. In one test with derris at 4 ounces per 1000 cubic feet on the bean aphid (*Aphis rumicis* L.) a very high kill was obtained. As yet no other insects have been tested.

In one experiment rotenone deposited on cornstalks and burned in the presence of nitrates was highly effective against flies. The amount of visible smoke was much less. The expense of preparing such a mixture is greater and could be justified except in special cases. Where a minimum of smoke is essential, this experiment points the way for further investigations.

The red color test for rotenone (1936) was made on the derris smoke at a dosage of 4 ounces per 1000 cubic feet. Immediately after the material was burned, 12 liters of smoke was drawn into an evacuated flask and shaken with acetone. The red color, in comparison with rotenone standards, indicated the presence of about 0.05 mg. per 12 liters, or less than 0.005 mg. of rotenone per liter. At the end of one hour about half as much rotenone was still suspended in the air. Although these tests definitely show the presence of rotenone or other similar substances, the amount is too small for accurate analysis. It should be pointed out that many toxic substances in derris do not give the red color test, and a considerable quantity of these may be present in the smoke. A large part of the insecticide is destroyed in the burning process but enough is dispersed in the air to be highly effective in killing flies.

DISCUSSION.—Pyrethrum smoke gave poor results in these tests, confirming past experience with this material which had led to the conclusion that burning is a wasteful method of applying easily decomposed organic insecticides. The results from derris smoke, however, indicated that this method should receive more attention. Since compounds of the rotenone series are so easily transformed into nontoxic substances, it is remarkable that an effective amount of unchanged material can be dispersed in smoke. If rotenone can be dispersed, it appears that other easily decomposed or nonvolatile insecticidal materials might be used as fumigants in the same way.

The application of toxic materials in the form of a smoke or aerosol has several advantages. The penetrating power of these suspensions is much greater than that of gases or vapors, because they are

not easily adsorbed on surfaces. They persist for long periods and cannot be precipitated easily except by a silent electric discharge. This method also broadens the field of fumigants, since solid compounds with little or no vapor pressure can be used. Furthermore, there is always the possibility of obtaining a toxic fumigant from a nontoxic substance by the burning process.

Smokes, of course, have disadvantages. Some may leave a visible deposit, and the odor may not be pleasant. The problem at hand is to increase the active smoke to a maximum and reduce the inert smoke to a minimum. In this way the total concentration of smoke can be greatly reduced. Objectionable odors can be masked by adding pleasant smelling materials such as pine needles, tobacco, or sandalwood. Rotenone or derris resin deposited on tobacco stems should approach these objectives. If an aerosol of solid insecticide could be prepared without resorting to burning, a great advance would be made, but a generally applicable procedure is as yet unknown.

The use to which such fumigants are put will depend on their improvement. With the reduction of the inert smoke it should be possible to fumigate dwelling houses and, if derris or cubé is used, the hazard of a fumigant toxic to man would be eliminated. This type of application may be useful in the eradication of dangerous mosquitoes, especially those carried from one country to another by airplanes. It might be possible to use smudges carrying toxic materials to combat mosquitoes in swampy areas. The use of derris for greenhouse fumigation may supplement the use of nicotine, since certain insects not affected by nicotine are killed by derris.

SUMMARY.—The effect of the smoke from a burning mixture consisting of 50 per cent derris, 30 per cent cornstalks, and 20 per cent sodium nitrate was tested against the housefly. The tests were made by exposing the flies in cages in a Peet-Grady chamber for 1 hour at 25° to 29° C. Derris smoke was more than ten times as toxic as the smoke from pyrethrum burned in the same way. The presence of rotenone in the smoke, even after one hour, was demonstrated by the Goodhue Red color test. In some preliminary tests aphids were also killed, but cockroaches were unaffected.

Although pyrethrum cannot be dispersed effectively by this method, the results of these tests show that derris may be applied in this manner. It appears, therefore, that other easily decomposed or non-volatile materials might also be used as fumigants.—11-17-39.

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# Certain Semi-Refined Oils for Summer Spraying on Apple Trees[1]

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Ever since highly refined, emulsified petroleum oils have become established in New Jersey as standard summer sprays for controlling codling moth and European red mite, the writer has been keenly interested in reducing the high cost of the oil. Many investigators of this problem have shown that unrefined petroleum fractions are likely to produce injury to foliage of deciduous fruit trees, especially when several successive sprays are applied during the growing season. This fact, coupled with the difficulties of controlling codling moth with lead arsenate alone in certain heavily infested areas brought forth expensive spray oils. In the urgency to control codling moth, no time was allowed to study the degree of refinement required to make petroleum oils comparatively safe on apple foliage. Consequently,

[1] Paper of the Journal Series, New Jersey Agricultural Experiment Station, Department of Entomology.

highly refined petroleum distillates, almost as costly as the medicinal or white oils, have been placed on the market for orchard spraying, whereas much cheaper, semi-refined oils might have answered the purpose just as well.

The investigations of Gray & DeOng (1926), DeOng *et al.* (1927), Ginsburg (1927, 1929, 1931, 1931), Spuler *et al.* (1931) and Green (1932) have definitely proved that unsaturated and aromatic hydrocarbons are chiefly responsible for the phytocidal properties of petroleum oils. It is the consensus of opinion among these investigators that a safe summer oil should be a paraffin distillate of the light lubricating type, of 65 to 80 viscosity, substantially free from readily reactive substances, such as unsaturated and aromatic hydrocarbons, but need not be highly refined. There are various processes for removing the reactive compounds from oil, such as treatment with sulfuric acid, bromine, iodine, and various solvents. The chemical and physical methods of oil refining are reviewed by Dunstan *et al.* (1938). The use of sulfuric acid as a refining agent for petroleum oils dates from the very early days of the industry. Today, although many changes have taken place in the refining of petroleum products sulfuric acid is still probably the commonest refining agent for light lubricating oils. The sulfonation test, therefore, or the per cent unsulfonatable residue (U.S.R.), is at present the simplest criterion of the degree of refinement of an oil distillate. Medicinal oils require the highest grade of refinement. For lubricating purposes partial refinement is, with few exceptions, sufficient.

Among the various types of lubricating oils there is a group, designated as "spindle or knitting oils," used in the lubrication of very light, high speed machinery. To produce this oil a petroleum distillate may be treated with 10 to 15 pounds of sulfuric acid per barrel (as compared with from 100 to 250 pounds, depending on the type of crude, required for white oils), neutralized with various concentrations of sodium hydroxide, washed with water, air blown and filtered through clay or similar absorbing material. Not all spindle oils receive all these treatments. In some oils "brightening," in others filtration, and in still others, both operations, may be omitted, which, of course, cheapens the refining process. These variations in refining produce corresponding differences in the price of spindle oils. While the above treatment is not sufficient to produce an odorless, colorless, tasteless, refined medicinal oil, it does remove most of the unsaturated and aromatic hydrocarbons, leaving the oil distillate from 80 to 84 per cent saturated. These oils are, therefore, classed as semi-refined and suggest themselves as suitable summer spray oils.

Briefly, it was the object of this investigation to study various types of spindle oils available on the market in order to select comparatively cheap summer oils which could be safely applied on apple trees to control insects.

PRELIMINARY TESTS IN 1933.—Several samples of semi-refined oils obtained from different oil companies were emulsified with one per cent soap and sprayed on young Stayman apple trees at concentrations of 0.5 and 1 per cent actual oil. Three successive sprays were applied in July and August, with a knapsack sprayer. Various degrees of foliage injury began to appear after the second spray, especially where the one per cent concentrations were applied, from the oils used with two exceptions. The two oils which produced no noticeable injury were paraffin distillates. One was a highly priced transformer oil while the other was a high grade spindle oil (sold at that time under the name of *White Rose*) possessing the following specifications: A.P.I. gravity = 31; viscosity = 93–98; U.S.R. = 83 per cent.

EXPERIMENTS IN 1937.—Due to more urgent work this investigation was temporarily suspended and was not resumed until 1937, when it was decided to block-test the above spindle oil in a commercial orchard. By this time the manufacture of *White Rose* oil had been discontinued. After examining the specifications of a large number of spindle oils, a semi-refined distillate was finally selected which was similar in its properties to *White Rose*, possessing the following specifications: A.P.I. gravity = 31; viscosity = 75–80; U.S.R. = 82–84 per cent; source = paraffin base. The oil was emulsified with 0.5 per cent sodium lauryl sulfate and sprayed on a block of some 24 apple tress containing Stayman, Wealthy and Rome varieties. Five sprays consisting of

0.5 per cent oil, 2 pounds lead arsenate, 2 pounds hydrated lime and 100 gallons of water were applied during June, July and August. The remainder of the orchard where this block is located received the same number of 0.5 per cent oil sprays but the oil used was highly refined, analyzing about 94 per cent U.S.R. This afforded the writer the first opportunity to compare the performance of the two grades of oil under identical conditions. Close observations throughout the season failed to disclose any appreciable differences between the two, either as to foliage injury or control of codling moth. In each case, slight oil injury and considerable arsenical burning appeared on foliage as has been generally observed on all late varieties. The extent of injury, however, was about the same from each of the two oils studied.

**Table 1.—Specifications of the oils tested in commercial orchards.**

| Oil number | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Block number | 8 | 9 | 10 | 11 |
| Base of oil | Paraffin | Paraffin | Paraffin | Intermediate |
| Viscosity Saybolt at 100°F | 70 | 75 | 65 | 70 |
| Per cent sulfonation | 90–94 | 82–84 | 82–84 | 82 |
| A.P.I. gravity | 37 | 31 | 32 | 31 |
| Viscosity index | 90–100 | 90–100 | 90–100 | 85–90 |
| Refinement | Highly refined | Semi-refined | Semi-refined | Semi-refined |
| Approximate cost per gallon, in tank car | 33 cents | 15 cents | 11 cents | 8 cents |

EXPERIMENTS IN 1939.—During 1938 a group of apple growers started to prepare home-made summer oil emulsions employing a highly refined oil of 70 viscosity. In 1939 the price of this oil had become so high that it was almost prohibitive for home-made emulsions. The writer was confronted with the problem of recommending a cheaper oil possessing the same efficiency as the highly refined type. It was then decided again to run orchard tests with the spindle oil tested in 1937 (designated here as oil No. 2) along with two other semi-refined oils of similar composition, for direct comparison with the highly refined oil. The specifications of the four oils are given in table 1.

In selecting the semi-refined oils the writer was guided by the following information. According to the revised classification of petroleum oils by Lane and Garton (1935), there are nine possible classes of crude oils, as follows:

1. Paraffin base: Distillates paraffinic throughout.
2. Intermediate base: Distillates intermediate throughout.
3. Naphthene base: Distillates naphthenic throughout.
4. Paraffin-intermediate base: Light fractions paraffinic; heavy fractions intermediate.
5. Intermediate-paraffin base: Light fractions intermediate; heavy fractions paraffinic.
6. Intermediate-naphthene base: Light fractions intermediate; heavy fractions naphthenic.
7. Naphthene-intermediate base: Light fractions naphthenic; heavy fractions intermediate.
8. Paraffin-naphthene base: Light fractions paraffinic; heavy fractions naphthenic.
9. Naphthene-paraffin base: Light fractions naphthenic; heavy fractions paraffinic.

About 85 per cent of the crude oil samples tested from the principal producing fields throughout the world fall definitely into the first three classes.

Thus, paraffin distillates need not be derived exclusively from paraffin crudes but can also be obtained from mixed bases such as intermediate-paraffin or even naphthene-paraffin. In these two crudes the heavy fractions run paraffinic. It is, therefore, possible to secure a distillate from a non-paraffin base crude which, when properly refined, can be safely used for summer spraying. As a matter of fact, with the refining processes available today, nearly all grades of lubricating oils, from the lowest to the highest, can be prepared from any type crude oil. On the other hand, naphthenic distillates, whether derived from naphthene crudes or mixed crudes, are high in unsaturated and aromatic hydrocarbons and must be subjected to more drastic and costly processes of refinement as compared with paraffin distillates, which are low in these reactive compounds. For these reasons the semi-refined oils selected for testing consisted of paraffin distillates derived from either paraffin or intermediate crudes.

Another characteristic which was closely watched in selecting the oils was viscosity index, commonly abbreviated to V.I. This is a function designed to express the

change of viscosity with temperature, generally at 100 to 210° F. Since paraffinic oils have a lower rate of change of viscosity with temperature than naphthenic oils, V.I. offers a valuable measure of "paraffinicity" of a given oil, bearing a direct relationship. Therefore, an oil with a high viscosity index will also be high in paraffin hydrocarbons and vice versa.

The main differences between the three semi-refined oils tested result from the process of refining. Oil No. 2 was treated with about 15 pounds of fuming sulfuric acid per barrel (50 gallons); neutralized with sodium hydroxide; washed with water; air-blown and filtered through clay. Oil No. 3 was subjected to the same treatments but was not filtered. Oil No. 4 was treated with smaller quantities of sulfuric acid; neutralized and washed. The oils were emulsified by one of the formulas previously tested, Ginsburg (1936), for home-made emulsions, as outlined in table 2.

BLOCK TESTS.—Four blocks were arranged in the orchard where the 1937 experiment was conducted. A block consisted of some 24 trees, eight from each of the following varieties: Stayman, Wealthy and Rome. All blocks were sprayed alike, according to the New Jersey codling moth spray schedule where several of the cover sprays require oil and lead arsenate in the first brood and oil with either lead arsenate or nicotine in the second brood. The only difference in the block treatments was in the kind of oil used. Five oil sprays of 0.7 per cent actual oil were applied on the following dates: June 5, 12, and 23; July 24 and August 1.

Close observations have shown no noticeable differences either in foliage injury or in codling moth control from the four oils. During July and early August arsenical injury made its appearance in all blocks, regardless of the kind of oil used, being more pronounced on Stayman, least on Wealthy and medium on Rome varieties. In general, oil as well as arsenical injuries in this particular orchard could be classified as slight with only a few instances where some Stayman trees showed appreciable foliage burn. After the third spray the highly refined oil in block 8 was discontinued and oil No. 2 was used for the last two spray applications.

ORCHARD TESTS.—In addition to the block tests, about 1000 gallons of oil No. 2 were distributed among five growers who were instructed to spray any suitable sections and varieties of trees in their orchards for comparison with the highly refined oil emulsion, either home-made or commercial, which they might use. Observations made by the growers and the writer after the first-brood spraying again revealed no noticeable differences between the two oils. Arsenical as well as some oil injury appeared in all orchards on certain varieties, particularly Baldwin, Grime and Winesap. The extent of injury, however, was about the same from both types of oil. As a direct outcome of these experiments, many growers have replaced the highly refined oil No. 1 with the semi-refined oil No. 2 in preparing their home-made emulsions for the second brood codling moth sprays, thereby realizing a considerable saving in cost of materials.

**Table 2.—Formula for summer home-made emulsion.**

| | |
|---|---|
| Oil | 100 gallons |
| Water | 42 gallons |
| Sodium lauryl sulfate (commercial) | 8 to 10 pounds |
| De-foamer (kerosene containing about 50 per cent wool fat) | 2 quarts |

An interesting comparison presented itself in two adjoining orchards of Walter Roberts and Aaron Collins. Mr. Roberts applied home-made emulsions prepared from oil No. 2, while Mr. Collins used a highly refined commercial emulsion. In each orchard six sprays of about 0.7 per cent oil were applied prior to August 17. Of the several varieties examined, Stayman showed appreciable arsenical and oil injury, accompanied by some leaf drop in both orchards. The amount of injury, however, was about the same in the two orchards, irrespective of the type of oil sprayed.

On the basis of the observations here reported, the writer feels justified in recommending a semi-refined paraffin distillate, of the types described under oils 2 and 3, for summer spraying of apple trees as a substitute for the highly refined oil heretofore used. The primary purpose of this suggested change is to reduce the cost of spraying for those orchardists

who are compelled to use summer oil in their efforts to control codling moth.

Concerning the type oil designated as No. 4, which is lowest in cost but is at the same time one of the less refined, the writer feels that it should be tested in commercial orchards for at least one more summer under close observation before it can be recommended.

SUMMARY AND CONCLUSIONS.—Experiments were conducted over a period of several years with petroleum distillates of varying degrees of refinement for the purpose of selecting a cheap oil which could be safely sprayed on apple foliage, as a substitute for the highly refined oil heretofore used. Blocks of apple trees, as well as entire apple orchards, containing different varieties were sprayed five to six times during one season with about 0.7 per cent oil, mixed with either lead arsenate or nicotine, to control first and second brood codling moth. From the results obtained it appears that a semi-refined paraffin distillate of about 70 viscosity and about 83 per cent sulfonation, possessing a viscosity index of 90–100 is just as safe for summer spraying on apple trees as is the highly refined oil. The cost of the semi-refined distillates is less than half as much as that of the highly refined oil.—11-17-39.

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# Field Tests for Rosy Aphid and Budmoth Control[1]

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The purpose of this paper is threefold: to report results with some of the newer dormant sprays on the control of rosy apple aphid during a severe infestation; to show the effects of the same materials on budmoth; and to introduce the "breaking bud application" with data on control of these two pests. All the experiments were made in the apple belt of western New York so, unless mentioned otherwise, all statements should be interpreted as referring to this area. From 1936 to 1938, during which period certain dinitro compounds were being tested as insecticides by workers at the Geneva Station, the rosy apple aphid, *Anuraphis roseus* Baker, was not very abundant. An "aphis year" occurred in 1939 which gave the writers their first opportunity for testing these newer insecticides during a severe outbreak of this species. The rosy apple aphid problem is closely related to the control of the eye-spotted budmoth, *Spilonola occellana* D & S. It is for this reason that the control of the two insects is considered in the present discussion.

The treatments that have given the most dependable results on both species during previous years have been spring dormant, green-tip, and delayed dormant applications. During some seasons, as in

[1] Approved December 11, 1939, by the Director of the New York State Agricultural Experiment Station for publication as Journal Paper 354.

1939, apple buds remain for nearly a week in a condition which is designated by the writers as the "breaking bud stage." Little was known regarding the safeness and effectiveness of treatments applied during this period. Some of the experiments herein recorded were aimed to cover this stage. The "breaking bud stage" may be described as the period beginning when about 10 per cent of the apple fruit buds show separation of the bud scales at the tips sufficient for green tissue to be seen by looking into the buds and ending when about 50 per cent of the buds show green tips protruding from the ends of the buds. As will be noted subsequently, a number of mixtures that in the past have proven to be very effective in later stages are rather ineffective if applied at the breaking bud stage. On the other hand, some mixtures at dormant concentrations may cause serious bud injury if applied in the breaking bud stage. Apparently some of the dormant spray mixtures can be modified to avoid bud injury and at the same time control aphids and budmoth while other mixtures can be used safely at certain dormant concentrations.

MATERIALS AND MIXTURES.—Two kinds of lubricating oil were used, namely, *Diamond Spray Oil*—viscosity 100 seconds, Saybolt at 100° F.—and an unnamed oil[2]—viscosity 108. Neither oil contained an emulsifier. The majority of oil emulsions containing dinitro-o-cyclohexylphenol were used with the second oil while *Diamond Spray Oil* was used in most other mixtures containing oil. In a few instances these oils were interchanged and it was found that the differences in control were so slight that the two oils may be considered as practically identical as regards insecticidal qualities. Lignin pitch (*Goulac*) was used to emulsify most of the *Diamond Spray Oil* mixtures. A special emulsifier was supplied by the Dow Chemical Company for the oil supplied by them.

Dinitro-o-cyclohexylphenol[3] was supplied in two types of mixtures; namely, oil solution and dry, mixed with other materials. The oil solution consisted of 4 per cent of the chemical and 96 per cent of oil by weight. It was emulsified in the spray tank by the use of a special emulsifier supplied by the Dow Chemical Company. The dry preparations consisted of dinitro-o-cyclohexylphenol with varying amounts of other materials and were added to the oil after it was emulsified in the spray tank. These will be designated Dry-mix DNOCHP. The phenol-oil preparation is marketed under the name *Dowspray Dormant* which, together with certain of the dry phenol mixtures when used with oil have been abbreviated to DN-oil in previous writings of the senior author. Since the several dry mixtures gave similar insecticidal control for any specific amount of toxicant, the results have been averaged in the tables.

A commercial preparation known as *Elgetol*[4] was tested extensively. This is said to contain a sodium salt of dinitro-cresol and other substances that probably serve to increase the efficiency of the cresol.

The nicotine used was *Black Leaf 40*. The high temperature tar oil was a commercial emulsion which in previous seasons gave results practically identical with tank-mix tar oil emulsions containing the same concentration of tar oil. The low temperature tar oil[5] was like that described by Worthley & Steiner (1939).

DORMANT APPLICATIONS.—The number of days when spraying could be done effectively during the spring dormant season of 1939 was far below the average. Treatment was made in several orchards when the weather was decidedly adverse. These climatic conditions greatly curtailed the number of trees receiving the various dormant mixtures, as it had been planned to replicate the treatments in a number of orchards. Table 1 gives the data secured with the various mixtures in orchards which were sprayed under moderately favorable weather conditions.

It will be noted that lubricating oil at 4, 5, and 6 per cent either alone or with nicotine sulfate, did not control the rosy aphid. The 5 and 6 per cent concentrations alone gave from moderate to good control of bud moth, while the addition of nicotine gave dependable increases only in the case of the 4 per cent oil. These results indicate that if 5 or 6 per cent oil sprays must be used to control fruit tree leaf roller, *Cacoecia argyrospila*

[2] Furnished by the Dow Chemical Company, Midland, Mich.
[3] Manufactured by the Dow Chemical Company, Midland, Mich.
[4] Manufactured by Standard Agricultural Chemicals, Inc., Hoboken, N. J.
[5] Manufactured by the Pittsburgh Coal Carbonization Company, Pittsburgh, Pa.

Table 1.—Control of rosy aphid and bud moth, 1939.

| Material | Amount per 100 Gallons | | Rosy Aphid | | Bud Moth | |
|---|---|---|---|---|---|---|
| | Oil* gallons | Toxicant ounces | Number trees | Per cent reduction | Number trees | Per cent reduction |
| **Dormant Applications** | | | | | | |
| Lubricating oil | 4 | 0 | 9 | 15 | 2 | 29 |
| Lubricating oil | 5 | 0 | 13 | 33 | 11 | 74 |
| Lubricating oil | 6 | 0 | 8 | 35 | 7 | 85 |
| Lubricating oil | 8 | 0 | 1 | 53 | — | — |
| Lubricating oil+nicotine | 4 | 16 | 3 | 0 | 2 | 89 |
| Lubricating oil+nicotine | 5 | 16 | 10 | 28 | 7 | 80 |
| Lubricating oil+nicotine | 6 | 16 | 7 | 64 | 4 | 82 |
| High temperature tar oil 3% | 0 | 384 | — | — | 2 | 59 |
| Low temperature tar oil 3% | 0 | 384 | — | — | 3 | 65 |
| Dinitro-o-cyclohexyphenol mixtures | | | | | | |
| *Dowspray Dormant* 1½% | 1.4 | 7.2 | 3 | 83 | — | — |
| *Dowspray Dormant* 2½% | 2.4 | 12.0 | — | — | 3 | 96 |
| *Dowspray Dormant* 3% | 2.9 | 14.4 | 3 | 92 | 8 | 93 |
| *Dowspray Dormant* 4% | 3.8 | 19.2 | 2 | 92 | 3 | 97 |
| Oil+dry-mix DNOCHP | 1.5 | 7.1 | 3 | 85 | — | — |
| Oil+dry-mix DNOCHP | 2.5 | 10.0 | — | — | 2 | 78 |
| Oil+dry-mix DNOCHP | 3.0 | 14.0 | 1 | 88 | — | — |
| Sodium-dinitro cresylate mixtures | | | | | | |
| *Elgetol* 1½% | 0 | ? | 2 | 98 | — | — |
| *Elgetol* 1% | 0 | ? | — | — | 4 | 97 |
| *Elgetol* 2% | 0 | ? | 3 | 95 | 6 | 99 |
| *Elgetol* 1%+oil 3% | 3.0 | ? | 1 | 90 | 2 | 96 |
| **Breaking Bud Applications** | | | | | | |
| Lubricating oil and nicotine | 3 | 16 | 44 | 41 | 15 | 73 |
| Lubricating oil and cresylic acid | 3 | 64 | 4 | 0 | 2 | 75 |
| Lubricating oil and high temperature tar oil | 3 | 64 | 7 | 58 | 2 | 62 |
| Lubricating oil and low temperature tar oil | 3 | 64 | 4 | 63 | 2 | 77 |
| Oil+dry-mix DNOCHP | 2 | 4.0 | 22 | 52 | 19 | 58 |
| *Elgetol* ½% | 0 | ? | 14 | 96 | 10 | 88 |
| *Elgetol* 1% | 0 | ? | 40 | 96 | 10 | 96 |

* Petroleum lubricating oil.

(Walk.), nicotine should be omitted in the dormant application and used in the delayed dormant treatment with bordeaux or lime-sulfur. Such a schedule would be effective against rosy aphid and would greatly improve the control of the budmoth.

The comparison of high temperature tar oil and low temperature tar oil was made at 3 per cent concentrations to give a better idea of the relative toxicity of the two materials. Unfortunately for the experiment, rosy aphid was not sufficiently abundant in this orchard to furnish dependable data. The results on budmoth indicate that the effectiveness of the two tar oils are much the same with a possibility of the low temperature tar oil being slightly the better. The difference is not sufficient to indicate that a 4½ per cent concentration would control a severe infestation of budmoth. The data do not indicate that the dry-mix DNOCHP used with oil differs much from *Dowspray Dormant*, at least as regards the effects on these two insects. Mixtures containing from 2½ to 3 gallons of oil and 12 to 14 ounces of the toxicant in 100 gallons of spray material gave good results on both insects. This would be the equivalent of from 2½ to 3 gallons of *Dowspray Dormant* per 100 gallons.

*Elgetol*, at concentrations of ½ gallon or higher, gave excellent control of rosy aphid, and at 1 gallon or more was very effective against budmoth. Unfortunately, there were no budmoths in the orchard where the half-gallon concentration was used. The addition of 3 per cent lubricating oil to *Elgetol*, 1 per cent, did not im-

prove the latter for the control of aphids and budmoth. On the other hand there appears to be no inhibitive action of the oil on the *Elgetol* as regards budmoth. The data are too meager to determine whether, in the control of the rosy aphid, the difference is due to tree variation or to the presence of the oil. The combination of oil and *Elgetol* was used to determine its value against fruit tree leaf roller, the control being decidedly better than with *Elgetol* alone, even at greater concentration.

BURSTING BUD APPLICATION.—A sudden early warm period of several days pushed the apple buds out of the true dormant stage into the breaking bud stage, after which a cold period held the buds in this condition for nearly a week. Opportunity was thus afforded to test the modified mixtures, shown in table 1, in a number of orchards.

In the use of dinitro-o-cyclohexylphenol the toxicant was reduced to 4 ounces and the oil to 2 gallons. The mixtures were used on a number of varieties and no bud injury occurred in any instance. These mixtures gave rather poor control of rosy aphids and a reduction of budmoth that would be effective only in a light infestation. The maximum quantity of toxicant that might be effective and also safe for the buds was not determined.

*Elgetol*, ½ gallon, gave excellent control of aphids and good control of budmoth. When used at the rate of 1 gallon per 100, excellent control of both insects was secured. No bud injury occurred on the several varieties on which the tests were made. Thus *Elgetol*, even as concentrated as 1 gallon per 100, may prove to be safe for use in the breaking bud stage in early spring.

Lubricating oil, 3 gallons, with either nicotine 1 pint or cresylic acid one-half gallon, has been recommended for full green-tip applications for rosy aphid, while for the same period oil-nicotine has proven effective for budmoth. Lately Hough (1939) has reported that a delayed dormant application consisting of lubricating oil 3 gallons and tar oil one-half gallon in 100 gallons of spray mixture has proved highly effective against rosy aphid in Virginia. All these mixtures were tested in the breaking bud stage and, in addition, a trial of low temperature tar oil and lubricating oil was made for comparison.

As will be noted in table 1, none of these mixtures was sufficiently effective against rosy aphid, but in the case of budmoth three of the mixtures (those with nicotine, cresylic acid or low temperature tar oil) gave moderate control; results comparable with those secured during previous years with high temperature tar oil, 4½ per cent, applied during the dormant stage (Hartzell 1939). Apparently *Elgetol* is the most promising spray tested for use in the breaking bud stage.

INFLUENCE OF WEATHER.—In both the dormant and the breaking bud stages weather conditions played an important role in the degree of control secured. The efficiency of practically all mixtures varied considerably and in a number of instances the results were very unsatisfactory despite the fact that proper concentrations were used. Lack of space prevents the inclusion of this data, but most failures can be ascribed to wind or rain. High wind accounts for most cases of poor control with treatments that otherwise should have given high efficiency; in fact most failures by growers during 1939 with recommended commercial materials can be charged to wind interference.

In some experiments, rain, occurring before the spray material had dried on the trees, greatly lowered the control by those mixtures containing nicotine with oil, *Dowspray Dormant*, or *Elgetol*. The influence of wind and rain needs more emphasis in recommendations for spraying with most dormant and early spring mixtures.—11-16-39.

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# Experiences in New York with Non-Residue Sprays for the Codling Moth[1]

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During an average season fruit growers in western New York apply several summer sprays to combat one full brood and a partial second of codling moth (*Carpocapsa pomonella* L.). Under favorable conditions the moths are present in the orchards continuously from the time the fruit is set until harvest; in other words from late May until the middle of September. Three or four sprays are required for combating the first brood worms, and one or two sprays for the second brood, depending on the severity of the infestation. During seasons favorable for insect development, second brood damage usually exceeds that caused by the first brood.

When arsenicals are used for protection over the full period of two to three months, provision is made for removing the objectionable residues. There are a few favored sections in which the codling moth is of minor importance and the residue problem is avoided. In the more heavily infested areas a small percentage of growers have installed their own cleaning machinery. However, in the majority of cases the apples are washed at the cold storage or packing plants.

Tender varieties such as the McIntosh, Cortland, Wealthy, and Rhode Island Greening predominate and considerable care must be exercised with these sorts to prevent bruising. Every effort is made by the growers to avoid unnecessary and rough handling, and a washing operation, when properly supervised, causes little or no important bruising. On the other hand, the cold storage plants are usually equipped with a minimum amount of cleaning machinery and, because of the tremendous rush at harvest time, the fruit is handled in anything but a satisfactory manner. It is usually dumped from the container onto the conveyor of the washing machine, which in turn is often overloaded and speeded up far beyond the rated capacity. We all know too well the results of rushing this operation. Growers are practically helpless to avoid such conditions as in most cases the storage plants afford the only means for cleaning the fruit. It is indeed heartbreaking to have beautiful crops of apples ruined for use in high quality packs as a result of rough treatment. For this reason many growers not equipped to wash are turning toward the non-residue spray programs as a means of avoiding these unsatisfactory conditions.

The non-wash or non-residue summer spray schedules in general use include lead arsenate in the calyx and first summer applications, followed by a nicotine spray for the remainder of the season. Nicotine in the form of *Black Leaf 155*, *Botano N*, *Black Leaf 40* or *Black Leaf 50*, is usually combined with a summer oil. In orchards where codling moth is of minor importance one of the non-lead arsenicals, such as calcium or zinc arsenate, may be used in the second, or with light applications in both the second and third summer sprays. This has been the practice in sections where the apple maggot is a major pest. When later sprays are necessary a nicotine mixture without oil usually affords adequate protection and avoids objectionable residue. Although there is considerable room for improvement in the present non-wash spray schedule, very encouraging progress has been made toward perfecting a usable program. At the present time the objective appears to be a summer spray schedule that fills the following requirements:

*First;* safe and efficient materials effective against all summer pests of the apple and comparable in cost with an arsenical program.

*Second;* a minimum number of applications which shall be approximately 100 per cent effective against the first brood, thereby avoiding the need for late season or second brood sprays.

*Third;* materials that leave the fruit free of objectionable residue.

As to the safeness of these spray mixtures, there have been two dangers: damage caused by too much oil, and russeting of the fruit and defoliation as a result of the use of fungicides.

[1] Approved December, 1939, by the Director of the New York State Agricultural Experiment Station for publication as Journal Paper No. 333.

Too much oil tends to dull the finish of the fruit and to retard normal coloring, but this danger has been largely avoided by using oils with a viscosity of from 55 to 65 seconds. Experience suggests that more than four or five applications of a two-thirds per cent oil are not desirable. Even this amount may be objectionable in certain instances.

Regarding the use of fungicides, the practice has been to concentrate efforts on the early season sprays to control apple scab and thereby to avoid the necessity of using these materials during the summer months. When a fungicide is desirable, copper materials have been used in the first cover spray and again occasionally during the summer. Under New York conditions there is usually more or less danger from copper sprays applied before the first of July. Hydrated lime tends to reduce the danger of injury and today no copper material is recommended without lime. Oil applied too soon following sulfur has also proved dangerous; however experimental evidence of the past season indicates that it is possible to use elemental sulfur in reduced amounts in the first summer spray and follow safely in two weeks with oil. If such a procedure can be followed with reasonable safety it may then be possible to avoid the use of copper during the danger period for that material.

In the past the great objection to the nicotine program has been its cost. However, considering the saving by avoiding a washing operation, the value of the oil-nicotine spray against other summer pests such as bud moth, aphids, scale insects, etc., and the premium paid for unwashed fruit, the cost of a nicotine program has not been excessive. One-half pint of 40 per cent nicotine sulfate is now considered sufficient to make up 100 gallons of spray whereas formerly one pint was the recommendation. This last year a new type of oil was tested at Geneva for possible use as a summer spray. It compared favorably with the commonly used white oils and sells for less than half their cost. This new product was used with perfect safety on fruit and foliage. Further work with this oil spray is planned for the coming year.

With regard to the efficiency of nicotine sprays for controlling the codling moth, it may be well to cite the results of a first brood spray program as used under orchard conditions this past season.

The value of concerted effort toward first brood extermination, thereby avoiding second brood sprays, has been recognized for a number of years. This past season, being unusually favorable for a large and destructive second brood, a thorough test of a non-residue schedule was highly desirable.

A block of Rhode Island Greening trees was selected. The planting consisted of three rows of twenty trees each, the trees being thirty years old and in good vigor. The orchard has always been well populated with codling moth, probably due to the practice of leaving a number of trees unsprayed each year in connection with experimental work. To insure a large population for the test, no summer sprays were applied during 1938. Fruit counts made at the end of that season gave an average of over 48 per cent wormy fruit. Large numbers of moths were taken in bait pails hung in the trees during late May of this year, showing the block to be heavily infested.

As previously mentioned, the season of 1939 proved to be very favorable for the codling moth and especially so for the second brood which was active from the latter part of July until well into September. Many orchards showing only minor worm injury at the end of the first brood were seriously damaged by the late season worms. This was the case in an orchard located about 200 yards from the test block, untreated trees in which were 87 per cent wormy fruits this past season. Two other trees (McIntosh seedlings) about 100 feet from the experimental orchard were sprayed with five cover sprays of lead arsenate during the summer and by actual count their crops were found to be 20 per cent and 41 per cent wormy. Stings were not considered in these counts, only the deep wormholes. These examples serve to illustrate the infestation existing in the neighborhood, and the sources of second brood reinfestation that might influence the test block.

Five applications of an oil-nicotine spray were made during the period of first brood activity as follows:

| | |
|---|---|
| First cover | June 10 |
| Second cover | June 20 |
| Third cover | June 27 |
| Fourth cover | July 5 |
| Fifth cover | July 17 |

Two formulae were used in the tests:

| | | |
|---|---|---|
| 1. | *Black Leaf 155* | 4 lbs. |
| | Nicotine sulfate | 1 pt. |
| | Summer oil emulsion | (83% oil) 3 qts. |
| | Water to make | 100 gallons. |
| 2. | *Black Leaf 155* | 4 lbs. |
| | Nicotine sulfate | ½ pt. |
| | Summer oil emulsion | 3 qts. |
| | Water to make | 100 gallons. |

These formulae contain at least twice the amount of nicotine that is generally recommended in a non-wash program for the reason that it was desirable to exterminate the first brood. The sprays were applied from both the tank and the ground to insure thorough coverage.

By the middle of July it was extremely difficult to find any sign of worm injury, although damage was common in nearby orchards. At harvest, September 18, the fruit was free from visible residue, showing only the natural bloom characteristic of the variety. Counts were made of the total yields of several trees and averaged less than 1 per cent stings and less than 2 per cent wormy for both plats, indicating the possibility of further reduction in the amount of nicotine. The wormy fruit appeared to be the work of the second brood. No scab developed as this disease was eliminated with thorough sprays of sulfur prior to the summer applications. It is evident from this experience during a season favorable for second brood injury that it is possible to control codling moth with first brood sprays only. However, other well sprayed orchards were observed in which moths from adjoining infested plantings spread into the moth-free area causing a noticeable amount of second brood damage.

The use of fixed nicotine may at times leave a small amount of visible residue. For this reason some growers prefer to use a small brusher hooked in with the grading equipment which removes the light residues and leaves a high polish on the fruit. On the other hand, sprays containing either nicotine sulfate or free nicotine, combined with oil, leave no visible deposit. Because of the many ways in which nicotine may be used effectively, it is usually possible for the grower to select an efficient program that results in little or no objectionable residue.

SUMMARY.—Although possible to wash tender varieties of apples satisfactorily when the operation is properly supervised, fruit growers in western New York not equipped with washing machinery have had very discouraging experiences as a result of rough treatment given the fruit when washed at the cold storages and packing plants. As a result of these conditions certain non-wash summer spray programs employing nicotine have become very popular during the past few years. By the use of nicotine mixtures it has been found possible to avoid excessive deposits of lead and arsenic on the fruit, and the cost has not been excessive when considering the advantages of the program. Experimental evidence has shown that nicotine sprays properly applied may be even more effective than lead arsenate for combating the codling moth. It has been possible in isolated plantings to practically exterminate the first brood worms, thereby avoiding the use of further summer sprays for the codling moth. The work here reported applies only to conditions existing in the northeastern portions of the country.—11-16-39.

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# Laboratory Studies of Codling Moth Larval Attractants

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Attractants, or lures, have frequently been employed both in the control of insects and in studies of insect problems. In most instances such materials have been used primarily to attract the adult of the species. In this connection considerable experimentation with baits for the adult of the codling moth (*Carpocapsa pomonella* L.) has been in progress for a number of years, but thus far comparatively little attention has been given to the possible use of attractants for the newly hatched codling moth larva.

It will be recalled that the codling moth larva does not feed on the surface

[1] The writer wishes to express his appreciation to Grace T. Babers and Marian P. White for their assistance in these studies.

of its host fruit but instead tears away the skin of the fruit and casts aside the particles so as to effect its entrance into the flesh on which it feeds. This habit of avoiding, to a considerable extent, the spray deposit, is one of the more important of the factors which have contributed to the difficulty in the control of this insect.

With the thought that this normal feeding procedure on the part of the larva might possibly be modified the writer has endeavored, from time to time, to induce the larva to feed on the poisonous spray deposit. Until recently, however, no success in attracting the larva was attained. During the past year further studies to find a larval attractant have been conducted and in some instances the results have appeared sufficiently promising to warrant calling them to the attention of other workers.

Before the experiments are described, the reader is reminded of certain general facts pertinent to the work on which this report is based. The term "larval attractant" is used in this paper to designate a substance which, when combined with a stomach poison, will entice the larva to the poison for feeding purposes. The tests reported herein were conducted in the laboratory by means of the apple-plug method (one larva per plug). All the attractants tested were water-soluble. Water-soluble attractants would probably be at a disadvantage in districts where rainfall is frequent, and it would therefore seem that the use of an adsorbent or of a water-insoluble coating would be desirable as a means of preventing the removal of the attractant by rain. The concentrations of these attractants were arbitrarily selected. In some cases perhaps the most effective concentration was used; in other instances it is possible that either higher or lower concentrations would have been more effective.

ATTRACTANTS TESTED.—In this paper are included a number of the more important results and observations in order to illustrate the possibilities of larval attractants for the codling moth. The compounds that showed promise as larval attractants are found in the chemical groups of carbohydrates, polyhydroxy alcohols, and dibasic hydroxy acids. The brown sugar used was a medium-brown grade containing about 87 per cent of sucrose, 4 per cent of invert sugar, 6 per cent of nonsugars, and 3 per cent of moisture. The insecticides used were lead arsenate, calcium arsenate, paris green, phenothiazine, nicotine bentonite, derris, and pyrethrum.

**Table 1.—Results of laboratory studies on codling moth larval attractants for use with lead arsenate.**

| Section | Spray Material, Pounds per 100 Gallons | | Number of Apple Plugs | Percentage of Apple Plugs | | |
|---|---|---|---|---|---|---|
| | | | | Wormy | Stung | Clean |
| A | Water | | 214 | 98.6 | 0.0 | 1.4 |
| | Lead arsenate | 4 | 419 | 27.2 | 45.6 | 27.2 |
| | Lead arsenate + brown sugar | 4 + 16 | 420 | 11.0 | 19.0 | 70.0 |
| | Lead arsenate + sucrose | 4 + 16 | 424 | 9.7 | 18.9 | 71.4 |
| | Lead arsenate + honey | 4 + 16 | 312 | 19.6 | 24.3 | 56.1 |
| | Lead arsenate + corn syrup | 4 + 16 | 105 | 11.4 | 35.2 | 53.4 |
| B | Water | | 105 | 87.6 | 1.0 | 11.4 |
| | Lead arsenate | 4 | 106 | 13.2 | 15.1 | 71.7 |
| | Lead arsenate + brown sugar | 4 + 8 | 110 | 4.5 | 7.3 | 88.2 |
| | Lead arsenate + brown sugar | 4 + 12 | 102 | 4.9 | 1.0 | 94.1 |
| | Lead arsenate + brown sugar | 2 + 12 | 109 | 13.8 | 1.8 | 84.4 |
| | Lead arsenate + brown sugar | 2 + 16 | 105 | 6.7 | 1.9 | 91.4 |
| C | Water | | 316 | 96.2 | 2.2 | 1.6 |
| | Brown sugar | 16 | 215 | 93.4 | 1.4 | 5.1 |
| | Summer-oil emulsion | 8 | 319 | 85.9 | 2.8 | 11.3 |
| | Lead arsenate | 4 | 310 | 28.7 | 43.9 | 27.4 |
| | Lead arsenate + summer-oil emulsion | 4 + 8 | 311 | 23.8 | 18.6 | 57.6 |
| | Lead arsenate + summer-oil emulsion + brown sugar | 4 + 8 + 16 | 316 | 0.9 | 3.5 | 95.6 |
| D | Water | | 109 | 96.4 | 1.8 | 1.8 |
| | Lead arsenate | 4 | 106 | 35.9 | 41.5 | 22.6 |
| | Lead arsenate + sorbitol | 4 + 16 | 103 | 4.9 | 4.9 | 90.2 |
| E | Water | | 105 | 96.2 | 1.9 | 1.9 |
| | Lead arsenate | 4 | 107 | 33.7 | 19.6 | 46.7 |
| | Lead arsenate + sorbitol (technical) | 4 + 16 | 107 | 3.7 | 1.9 | 94.4 |
| F | Water | | 103 | 97.1 | 1.0 | 1.9 |
| | Lead arsenate | 4 | 109 | 41.3 | 35.8 | 22.9 |
| | Lead arsenate + dextrose | 4 + 16 | 107 | 31.8 | 16.8 | 51.4 |
| G | Lead arsenate | 4 | 216 | 39.8 | 34.7 | 25.5 |
| | Lead arsenate + galactose | 4 + 16 | 103 | 29.1 | 22.3 | 48.6 |
| | Lead arsenate + d-fructose | 4 + 16 | 216 | 17.1 | 7.0 | 75.9 |
| H | Water | | 103 | 99.0 | 0.0 | 1.0 |
| | Lead arsenate | 4 | 106 | 61.3 | 14.2 | 24.5 |
| | Lead arsenate + glycerine | 4 + 16 | 102 | 45.1 | 13.7 | 41.2 |
| | Lead arsenate + malic acid | 4 + 16 | 106 | 39.6 | 9.4 | 51.0 |

In table 1 are given the results obtained with lead arsenate when combined with various possible attractants.

In section A of table 1 it will be noted that when brown sugar, sucrose, honey,

or corn syrup was added to lead arsenate a lower percentage of injury resulted then when lead arsenate was used alone. With respect to the percentage of wormy plugs, honey appeared to be somewhat inferior to the other three sweets as a larval attractant, but was relatively effective in preventing stings.

A further study of the effect of brown sugar is given in section B. Although in this experiment lead arsenate alone gave a higher mortality than usual, its effectiveness was increased when brown sugar was added.

Summer-oil emulsion is frequently used in combination with lead arsenate because of its value as an ovicide and as an adhesive. Since it was believed that the addition of summer-oil would improve the permanence of the lead arsenate-brown sugar mixture, a test was made to determine whether the effectiveness of brown sugar as a larval attractant would be lowered in the presence of oil. As shown in section C of table 1, the mixture of lead arsenate, brown sugar, and summer oil emulsion was markedly more effective than any other spray. An analysis of variance by standard methods showed that the difference between the mean percentage wormy where this mixture was used and that from lead arsenate plus summer-oil emulsion is statistically highly significant (odds of 99 to 1).

**Table 2.—Results of laboratory studies on codling moth larval attractants for use with calcium arsenate, Paris green, nicotine bentonite, and phenothiazine.**

| Section | Spray Material, Pounds per 100 Gallons | | Number of Apple Plugs | Percentage | | |
|---|---|---|---|---|---|---|
| | | | | Wormy | Stung | Clean |
| A | Calcium arsenate | 4 | 102 | 37.2 | 26.5 | 36.3 |
| | Calcium arsenate<br>brown sugar | 4<br>16 | 103 | 7.6 | 11.4 | 81.0 |
| B | Paris green | 2 | 107 | 17.8 | 32.7 | 49.5 |
| | Paris green<br>brown sugar | 2<br>16 | 106 | 15.1 | 10.4 | 74.5 |
| | Paris green | 4 | 104 | 16.3 | 23.1 | 60.6 |
| C | Nicotine bentonite | * | 103 | 77.7 | 5.8 | 16.5 |
| | Nicotine bentonite<br>brown sugar | *<br>16 | 105 | 10.5 | 1.9 | 87.6 |
| | nicotine bentonite<br>molasses | *<br>16 | 107 | 28.0 | 7.5 | 64.5 |
| D | Phenothiazine | 1 | 107 | 56.1 | 12.1 | 31.8 |
| | Phenothiazine<br>brown sugar | 1<br>16 | 104 | 23.1 | 2.9 | 74.0 |
| | Phenothiazine<br>molasses | 1<br>16 | 102 | 17.6 | 4.9 | 77.5 |

* Containing 0.025 per cent of nicotine.

Sorbitol plus lead arsenate (section D) was definitely superior to lead arsenate alone, and this difference is significant. A technical grade of sorbitol was likewise effective as a larval attractant (section E).

The use of dextrose with lead arsenate appeared to increase the mortality over that obtained with lead arsenate alone (section F). The addition of d-fructose to lead arsenate enhanced its effectiveness to a greater extent than did galactose (section G).

Laboratory observations have shown that when drops of water are available the newly-hatched codling moth larvae are frequently attracted to the water and drink it. This habit was therefore considered a possible factor in the attractiveness of the sugars and other compounds on account of their water content. In order to determine the part played by moisture as a larval attractant, glycerine was tried because of its hygroscopic properties. Glycerine, however, is also somewhat sweet and for this reason it was concluded that this test could not be used as a criterion. The results indicated that glycerine may have improved the effectiveness of lead arsenate (section H).

In section H are given the results obtained with malic acid, which is found in unripe apples and in many other fruits and vegetables. Lead arsenate plus malic acid gave greater mortality than lead arsenate alone.

Another suggested explanation as to why the addition of brown sugar to lead arsenate caused greater mortality than lead arsenate alone was that the soluble arsenic content of the mixture might have been greater. This was proved, however, not to be the case. Chemical analyses[2] of these spray mixtures were made after 24 hours, during which period they received intermittent shaking. It was found that the solution of lead arsenate alone contained 8.5 milligrams of arsenic pentoxide per liter and the solution of lead arsenate plus brown sugar 8.2 milligrams. This difference is negligible.

Table 2 gives the results obtained when calcium arsenate, paris green, nicotine bentonite, and phenothiazine were used with certain attractants.

[2] Analyses by C. C. Cassil, Bureau of Entomology and Plant Quarantine.

In section A of table 2 it will be noted that the spray combination of calcium arsenate and brown sugar was markedly more effective than calcium arsenate alone.

Paris green at the rate of 2 pounds per 100 gallons plus brown sugar was significantly more effective in preventing stings than paris green alone at the rate of either 2 or 4 pounds per 100 gallons (section B). The difference in survivals, however, was negligible.

Both brown sugar and molasses increased the effectiveness of nicotine bentonite, as shown by the data in section C. of table 2.

Phenothiazine, at a purposely reduced dosage, was likewise considerably improved for insecticidal use when either brown sugar or molasses was added to it (section D).

It would seem reasonable to infer from the foregoing experiments (tables 1 and 2) that the addition of brown sugar to any insecticide would be likely to increase its effectiveness. But in tests with derris and pyrethrum, the results of which are shown in table 3, it was found that the addition of brown sugar did not increase the effectiveness of these materials. The explanation may be that derris and pyrethrum kill the codling moth larva largely through contact action. If this is true, a larval attractant would have little, if any, value.

SUMMARY AND CONCLUSIONS.—Laboratory studies were made of various sugars and other materials as possible larval attractants for use in increasing the effectiveness of lead arsenate and other stomach poisons in codling moth control. A larval attractant is particularly needed for more effective control of this insect because of the larva's natural avoidance of the insecticide deposit on the skin of the fruit. This field of investigation has apparently hitherto received but little consideration.

Of the several compounds reported in this paper, brown sugar, because of its availability and low cost, appears to offer greatest promise as a larval attractant. The addition of brown sugar to lead arsenate, calcium arsenate, nicotine bentonite, and phenothiazine considerably increased the toxicity of these insecticides under laboratory conditions. In combination with paris green it decreased the percentage of injury. With pyrethrum, however, brown sugar was not notably effective as an attractant and with derris it had no value. It is thought that derris and pyrethrum may kill the codling moth larva largely by contact action.

The hexahydroxy alcohol, sorbitol, was used only with lead arsenate, with which it was very effective. Other compounds which definitely improved the effectiveness of lead arsenate were sucrose, corn syrup, d-fructose, glycerine, and malic acid. Although smaller differences in survivals resulted from the use of honey, dextrose, and galactose, these compounds reduced appreciably the number of stings. Molasses, which was used only with nicotine bentonite and phenothiazine, increased the effectiveness of both these insecticides.

**Table 3.—Results of laboratory studies on codling moth larval attractants for use with derris and pyrethrum.**

| Section | Spray Material, Pounds per 100 Gallons | | Number of Apple Plugs | Percentage | | |
|---|---|---|---|---|---|---|
| | | | | Wormy | Stung | Clean |
| A | Derris (rotenone 5%) | 4 | 103 | 39.8 | 11.7 | 48.5 |
| | Derris (rotenone 5%) | 4 | 94 | 42.5 | 9.6 | 47.9 |
| | Brown sugar | 16 | | | | |
| B | Pyrethrum | 4 | 109 | 36.9 | 21.1 | 42.2 |
| | Pyrethrum | 4 | 108 | 28.7 | 14.8 | 56.5 |
| | Brown sugar | 16 | | | | |

Summer-oil emulsion was tested in combination with brown sugar and lead arsenate. This spray gave excellent results, indicating that the presence of summer-oil does not interfere with the attractiveness of brown sugar.

Throughout this study the data have shown that the percentage of stings was usually markedly reduced by the addition of a larval attractant to the insecticide. This is a good indication that when an attractant was added a higher percentage of the larvae ingested a toxic dose before they ruptured the skin of the apple than when an attractant was not used with the poison.

The reason why certain substances are effective as larval attractants is not known but there is considerable indication that many materials which are sweet to our taste are also palatable to newly-hatched codling moth larvae.—11-17-39.

# Mass Liberation of Parasites of the Oriental Fruit Moth for Immediate Reduction of Infestation[1]

M. H. Brunson, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*[2]

Numerous reports have appeared in entomological literature that pertain to the liberation of parasites of the oriental fruit moth (*Grapholitha molesta* (Busck)) for establishment in new areas. Definite information regarding the mass liberation of parasites for the purpose of an immediate reduction of fruit infestation, however, is limited. Daniel (1936) reported favorable results in reducing peach fruit infestation by the mass liberation of *Macrocentrus ancylivorus* Roh. in an orchard near other orchards in which no parasites were liberated that year. The investigations described in the present paper were carried on in 1938 to determine whether mass liberations of parasites would increase the parasitism of first- and second-brood larvae of the oriental fruit moth and reduce the subsequent peach fruit infestation in orchards in an area where larval parasites of the oriental fruit moth were already present in considerable numbers.

Methods.—Three orchards located in Mercer County, N. J., were selected to receive periodic liberations of *Macrocentrus ancylivorus* and *Bassus diversus* Mues., both parasites of larvae in twigs. Two orchards, one in Middlesex County, N. J., and one in Bucks County, Pa., were selected as controls. The orchards contained several varieties of peaches but a portion of each was planted to the Elberta or some variety ripening at about the same time. The orchards had not been bearing more than 3 years. They were one-half mile or more from any other peach orchard and were on an average $6\frac{1}{2}$ miles from each other, the greatest distance being 10 miles.

Parasite liberations were made on both first- and second-brood larvae, a greater

**Table 1.—Liberations of oriental fruit moth parasites in the various orchards.**

| Orchard | Number of Trees | Species | Date | Females Liberated | |
|---|---|---|---|---|---|
| | | | | Total Number | Average Number per Tree |
| Lipman | 278 | *B. diversus* | May 18 | 293 | 3.3 |
| | | | June 1 | 117 | |
| | | *M. ancylivorus* | June 30 | 299 | |
| | | | July 5 | 199 | |
| Maple | 1,149 | *B. diversus* | May 18 | 1,196 | 3.7 |
| | | | May 28 | 195 | |
| | | *M. ancylivorus* | May 28 | 120 | |
| | | *B. diversus* | June 1 | 192 | |
| | | | June 30 | 1,087 | |
| | | *M. ancylivorus* | July 5 | 1,187 | |
| | | | July 13 | 100 | |
| | | | July 22 | 98 | |
| Holcombe | 1,113 | *B. diversus* | May 18 | 1,119 | 4.1 |
| | | *M. ancylivorus* | May 20 | 158 | |
| | | *B. diversus* | June 1 | 196 | |
| | | | June 13 | 126 | |
| | | *M. ancylivorus* | June 30 | 1,091 | |
| | | | July 5 | 1,184 | |
| | | | July 13 | 97 | |
| | | *B. diversus* | July 21 | 467 | |
| | | *M. ancylivorus* | July 22 | 92 | |

[1] The owners of the orchards used for parasite liberations were I. B. Lipman, Washington Crossing, N. J.; C. L. Maple, Princeton, N. J.; and H. B. Holcombe, Trenton, N. J. The owners of the control orchards were Princeton Nurseries, Princeton, N. J.; and H. Heston, Newtown, Pa.

[2] The author is indebted to H. W. Allen for his general supervision of this work.

number on the second brood than on the first brood. *Bassus diversus* was liberated principally on the first brood and *Macrocentrus ancylivorus*, for the greater part, on the second brood. In table 1 are shown the number of female parasites liberated, the average number per tree, and the number of trees in the orchards. The control orchards, in which no parasites were liberated, contained 2,785 and 275 trees, respectively.

The trees selected for sampling were every fifth tree in every fifth row in each of the five orchards, and these were designated by number. The number of sample trees in the different orchards ranged from 16 to 140. At intervals of 4 to 9 days throughout the season the twigs showing new and old injury were cut and fallen immature fruits were collected from the sample trees in each orchard. The newly injured twigs and the drops were brought to the insectary and placed in containers with corrugated paper strips in which the larvae formed cocoons. The material from the individual trees was not kept separate but that from the different orchards was. The moths and the parasites emerging from the cocoons obtained from each orchard at each date of collection were recorded separately.

About 10 days prior to the usual ripening date of the variety Elberta the average fruit load of the Elberta trees, or varieties ripening at about the same time, was determined in each of the orchards by counting the fruits on 20 trees. While the fruits of these varieties were being harvested, the percentage of infested fruits on the trees in each orchard was determined by collecting, cutting, and examining for worm injury 8 samples of 50 fruits each. The trees used in determining the fruit load and those used earlier in the season to determine twig infestation and parasitism were disregarded in collecting fruit samples. The fruits were taken from the trees by a "staggered" method. The same number of fruits were taken from each tree sampled. To insure that the samples were selected entirely at random, the workers took them from the trees by the sense of touch, without looking directly at the tree or the fruit. They took the samples while going in eight different directions in the orchard. All ripe drops were also examined from 20 trees in the block in which the fruit load had been determined. The infestation figures for the drops were combined with those for the infested fruits on the trees.

In the treatment of the data obtained in this study two methods might be used in comparing the orchards. These are using as a basis for comparison (1) the average sample tree and (2) the acre. Since the number of trees per acre and the number of fruits per tree vary in practically all orchards, the number of fruits per acre may vary considerably, which in turn might influence the percentage of infested fruits per acre and possibly the number of worms per acre. Because of these variables the use of the acre as a basis for the comparison of orchards might not show the differential that would be shown by a smaller unit such as the average sample tree. There may be, however, a variation in the size of the trees, which may result in a variation in the number of fruits per tree in the different orchards. This possible error was virtually eliminated by choosing orchards in which the trees were of practically the same size. In this paper, however, the presentation of the data will be made for the greater part using both the average sample tree and the acre as the unit for comparisons of the orchards.

RESULTS.—Newly injured twigs were first found in the orchards soon after new twig growth began. The first collection was made on May 17 and the last on August 8, at which time twigs had become hardened in some of the orchards. The number of newly injured twigs collected per sample tree each collection date varied throughout the season in accordance with the periodic abundance of moths in the orchards. Injured twigs were most abundant early in July, following the emergence of first-brood moths. In general, first-brood larvae predominated in the orchards from May 17 to June 30 and second-brood larvae from July 1 to August 1. Third-brood larvae began to appear after August 1.

During the early part of June immature fruits began to drop. Although drops occurred in greatest abundance during June, they were found in varying numbers throughout the season. The number of oriental fruit moth larvae that were obtained from the drops was relatively small. Data regarding the number of infested twigs and drops collected are not

**Table 2.—Parasitism of oriental fruit moth larvae collected periodically in the different orchards.**

| Collection Period | Lipman | | Maple | | Holcombe | | Princeton Nurseries* | | Heston* | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Larvae per Tree | Parasitism | Larvae per Tree | Parasitism | Larvae per Tree | Parasitism | Larvae per Tree | Parasitism | Larvae per Tree | Parasitism |
| May 17–19 | 0.30 | 26.7% | 0.80 | 17.5% | 1.10 | 24.5% | 0.0 | 0.0% | 5.19 | 12.5% |
| 24–25 | .52 | 67.3 | .93 | 35.5 | .87 | 35.6 | .45 | 13.3 | 3.44 | 7.5 |
| 27–31 | .57 | 36.8 | .51 | 37.2 | 1.33 | 37.6 | .56 | 1.8 | 1.19 | 0.0 |
| June 1– 4 | .35 | 57.1 | .96 | 43.7 | .67 | 67.2 | .18 | 5.5 | 3.50 | 7.4 |
| 6– 9 | 1.08 | 47.2 | .79 | 41.8 | .60 | 50.0 | .45 | 6.7 | 1.88 | 6.9 |
| 10–15 | 2.60 | 37.3 | .61 | 49.2 | .69 | 26.7 | .08 | 0.0 | 1.37 | 20.4 |
| 16–21 | .61 | 37.4 | .27 | 53.7 | .06 | 33.3 | .11 | 0.0 | .31 | 19.3 |
| 22–29 | .30 | 33.3 | .23 | 78.3 | .03 | 66.6 | .33 | 36.4 | 1.43 | 41.9 |
| 29–July 8 | .70 | 92.8 | 5.37 | 69.8 | 9.51 | 76.4 | 10.98 | 61.9 | 14.00 | 78.8 |
| July 9–15 | 3.30 | 89.7 | 7.62 | 96.7 | 5.62 | 93.2 | 11.10 | 74.9 | 11.75 | 90.5 |
| 18–25 | 1.52 | 90.8 | 1.37 | 87.6 | 3.21 | 93.4 | 1.40 | 73.6 | 2.19 | 57.1 |
| 26–27 | .65 | 81.5 | .68 | 52.9 | 1.54 | 63.0 | .29 | 86.2 | .19 | 31.6 |
| 29–Aug. 3 | .52 | 59.6 | .33 | 81.8 | 2.03 | 79.3 | 4.34 | 29.7 | .19 | 68.4 |
| Aug. 4– 8 | .91 | 73.6 | .64 | 98.4 | 3.17 | 87.4 | 7.78 | 49.7 | .25 | 0.0 |
| Total or average (weighted) | 13.93 | 66.52% | 21.11 | 73.96% | 30.34 | 75.51% | 38.05 | 57.23% | 46.88 | 54.07% |

* Control.

included, as the twigs had no bearing on this study other than to furnish the desired larvae.

In table 2 are shown the average number of larvae collected per sample tree and the percentage of parasitism for each collection period in each of the orchards studied.

Several species of larval parasites occurred in varying degrees of abundance in the orchards studied, but only the following five are worthy of mention: *Macrocentrus ancylivorus*, *Glypta rufiscutellaris* Cress., *Pristomerus ocellatus* Cush., *Bassus diversus*, and *M. delicatus* Cress. In four orchards *M. ancylivorus* was the dominant parasite, whereas in one orchard in the same vicinity *G. rufiscutellaris* was dominant. In table 3 are given the five principal parasites and their relative percentages of the total parasites reared.

Table 4 shows the average number of first- and second-brood larvae collected per tree, parasitism, and moth survival, together with the fruit infestation per tree and per acre. The average number of larvae collected per tree represents the average number of moths and parasites reared per tree from the twigs collected. The average moth survival per tree represents the average number of nonparasitized larvae collected per tree and reared to adults.

Discussion of Results.—That mass liberation of larval parasites may reduce fruit injury by the oriental fruit moth is definitely indicated by the higher percentage of parasitism and fewer infested ripe fruits in the orchards that had received parasites than in the orchards that had not received parasites (table 4). The results show a definite relation between the degree of larval parasitism and the number of infested ripe fruits per tree and per acre. Also, the data show that different species of parasites may predominate in different localities in the same general area (Table 3). That such a condition exists in regard to the oriental fruit moth has been shown very conclusively by Driggers (1930).

It will be seen from table 2 that the

**Table 3.—Relative abundance of the principal oriental fruit moth parasites.**

| Orchards | M. ancylivorus | G. rufiscutellaris | P. ocellatus | B. diversus | M. delicatus | Total Parasites Reared |
|---|---|---|---|---|---|---|
| Lipman | 51.1% | 25.9% | 5.9% | 14.1% | 1.5% | 135 |
| Maple | 52.9 | 28.9 | 6.1 | 5.7 | 1.6 | 559 |
| Holcombe | 74.9 | 16.3 | 2.3 | 2.9 | 2.0 | 734 |
| Princeton Nurseries (control) | 22.6 | 74.5 | .8 | — | 1.1 | 1,976 |
| Heston (control) | 61.8 | 24.9 | 5.8 | — | 5.8 | 241 |

**Table 4.—Oriental fruit moth larvae collected, moth survival, parasitism, and fruit infestation in the various orchards.**

| Orchards | Average Larvae per tree | | Parasitism per cent | | | Average Moths per cent | | Average Ripe Fruits per Tree | Average No. Infested Fruits | |
|---|---|---|---|---|---|---|---|---|---|---|
| | First Brood | Second Brood | First Brood | Second Brood | Average (Weighted) | First Brood | Second Brood | | Per Tree | Per Acre |
| Lipman | 6.3 | 7.6 | 44 | 85 | 66 | 3.5 | 1.1 | 163 | 18.4 | 2,011 |
| Maple | 5.1 | 16.0 | 39 | 85 | 74 | 3.1 | 2.4 | 75 | 19.6 | 2,004 |
| Holcombe | 5.2 | 25.1 | 38 | 83 | 75 | 3.2 | 4.2 | 533 | 29.7 | 2,673 |
| Princeton Nurseries (control) | 1.7 | 36.3 | 6 | 59 | 57 | 1.6 | 14.7 | 387 | 69.1 | 5,946 |
| Heston (control) | 16.9 | 30.0 | 9 | 79 | 54 | 15.3 | 6.3 | 660 | 158.3 | 16,933 |

percentage of larval parasitism was considerably higher in orchards receiving parasites than in orchards not receiving parasites. As may be calculated from table 4, the average first-brood parasitism in orchards receiving parasites was five times as great as in those not receiving parasites. The average second-brood parasitism in orchards receiving parasites was 1.2 times as great as in those not receiving parasites. The average parasitism for both broods in orchards receiving parasites was 1.3 times as great as in those not receiving parasites. Also, the average number of infested ripe fruits per tree in orchards not receiving parasites was five times as great as in those not receiving parasites. A corresponding result is shown in the average number of infested ripe fruits per acre. The average number of second-brood moths that survived was four times as great in the orchards not receiving parasites as in the orchards receiving them.

In so far as these data are concerned, the deduction may be drawn that the mass liberation of parasites increased larval parasitism and decreased the ripe-fruit infestation in the three orchards in which parasites were liberated.

SUMMARY.—To determine whether mass liberations of parasites of the oriental fruit moth would reduce fruit infestation, a detailed study was made in 1938 in three peach orchards that had received liberations of *Macrocentrus ancylivorus* Roh. and *Bassus diversus* Mues. and in two orchards that had received no parasites. The peach orchards were located in Mercer and Middlesex Counties, N. J., and in Bucks County, Pa. Parasitism of the first- and second-brood fruit moth larvae was greater and the ripe-fruit infestation was less in the orchards receiving parasites than in the orchards receiving no parasites. The results obtained appear to show a definite relation between the percentage of larval parasitism and the number of ripe fruits infested per tree and per acre. Also, it was shown that in different parts of the same general area different species of parasites predominate.—11-17-39.

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# Effect of Larval Parasitization of the Oriental Fruit Moth on Infestation

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During the season of 1938 detailed observational experiments on the relationship between parasitization of the oriental fruit moth (*Grapholitha molesta* (Busck)) and the subsequent infestation in peach fruit were carried on near Moorestown, N. J. These studies were undertaken because of the scarcity of data bearing on the common belief among growers and entomologists that parasites are an im-

portant factor in the control of the oriental fruit moth. In view of the continued interest in these parasites and the large amount of work and money that is being spent on rearing and distributing them, it is surprising how little has been done to determine the effect of parasitization on fruit infestation.

Perhaps the most extensive studies of this nature have been conducted by Daniel and associates, of the New York Agricultural Experiment Station at Geneva (Daniel 1932; Daniel *et al.*, 1933; and Daniel 1936). Observations made by these workers in Niagara County, N. Y., during several successive years indicated a correlation between parasitization and fruit infestation. This relationship is of such importance in determining the possibilities of further economic work with the parasites of the fruit moth that the writers are convinced that considerable supplementary information should be obtained.

To determine the correlation that may exist between larval parasitization and infestation in ripe fruit is not a simple matter. Frequent sampling of the population in twigs is necessary, and the material must be reared to determine the percentage of parasitization. The sampling of fruit at harvest time presents a number of difficulties. For reliable data on infestation it is necessary to cut a number of fruits, since in many cases there is no superficial indication of the presence of the insect. It has been shown by Daniel (1932) that the invisible fruit injury varies from less than 40 per cent to more than 300 per cent of the visible injury. The percentage of injury is influenced considerably by the size of the crop and data on the number of fruits per tree are therefore needed. Satisfactory counts can not be made at the packing shed, since a considerable part of the injury may occur in the ripe drops or in fruit discarded by the pickers. Records are also needed on infestation and parasitization in immature fruits, which may have an important bearing on the subsequent infestation, and the data should be adjusted for this factor.

Extensive observations were made on amount of infestation and parasitization, and their fluctuation, for one season in a number of orchards within a restricted district.

The discussion of parasitism in this paper is restricted to the parasites attacking the fruit moth in the twigs and immature fruit of peach and to the two broods of fruit moth larvae occurring before the harvesting of the main commercial varieties of peach. Such parasitization is referred to as larval parasitization. Discussion of ripe-fruit infestation is limited to that occurring in the so-called mid-season varieties, including Elberta and others ripening at about the same time.

PROCEDURE.—The locality selected for this test was Burlington County, N. J. This is an important peach-growing district with many commercial orchards. There has been heavy parasitism by *Macrocentrus ancylivorus* in this district for many years. Weather conditions are generally favorable for rapid multiplication of the fruit moth; in 1938 they proved to be more favorable than usual. Eight orchards were included in the test; these were distributed over an area of about 9 by 14 miles. Owing to the large number of orchards in this district, it was impossible to secure locations sufficiently isolated to eliminate completely the factor of moth migration from other orchards. Orchards 1 and 2 were on the same property and separated at one point by only 90 feet. Orchards 7 and 8 were also on one property and separated at one point by 390 feet. The others were located from $\frac{1}{3}$ mile to several miles from the nearest peach orchard.

Owing to extensive planting of several new varieties of peach during recent years, it was not feasible to obtain eight orchards containing blocks of bearing trees of the same variety. All the orchards, however, contained blocks of bearing Elberta or some other variety ripening at about the same time. The trees ranged in age from young bearing to old bearing.

Fruit moth population and parasitization of the first two broods were determined for each of these orchards by making frequent collections of infested twigs and immature drops from a series of sample trees. The same sample trees were used over the entire observation period and were scattered uniformly over the orchard, generally every fifth tree in every fifth row. This method of sampling eliminated any large error due to wide variations in population density of parasites or host within the limits of the orchard. As may be computed from table 1, the pro-

portion of sample trees ranged from 6.1 per cent in the largest orchard to 10.9 per cent in the largest orchard to 10.9 per cent in the smallest. At intervals, from the middle of May until the middle of August, the infested twigs and immature drops were collected and taken to the laboratory for rearing of moths and parasites. The number of freshly wilted twigs, which is a quantity intermediate between the total number of infested twigs and the number of larvae reared, was selected as the best measure obtainable for fruit moth infestation in twigs. The number of infested twigs represents a quantity greater than the worm population, since the growing worms migrate freely from one twig to another, one worm sometimes entering several twigs in the course of its development. The number of larvae reared would be less than the larval population owing to mortality in rearing and to the fact that some larvae which would complete their development and disappear from the twigs between collections would be missed.

The first two collections included all the drops under all the sample trees, but the number of drops later became so large that it was necessary, during the remainder of the season, to restrict the samples to the drops under one-fifth of each sample tree.

The importance of the infestation in immature drops varies and in careful observations can scarcely be ignored. Its influence on the subsequent infestation in fruit is not always small. Although the infestation in immature drops has never been found to equal that in twigs, parasitism is invariably less, and thus the proportion of moths surviving parasitization is relatively higher and sometimes important in evaluating the relationship between parasitization and ripe-fruit infestation. For instance, in one orchard under observation in another district, and not included in the data presented in this paper, computations based on twigs alone indicated that parasitization was 76.7 per cent and the number of moths per tree surviving parasitism 2.41. When adjustment was made for the immature-fruit infestation, the value for parasitization was reduced to 66.5 per cent and the number of moth survivors per tree increased to 4.67.

For determining the ripe-fruit infestation a portion of each orchard was selected for sampling shortly before harvest. The area of each sample block was determined, and counts were made of the bearing trees and the fruit on 20 sample trees selected from an orchard map. The sample for determining infestation was a composite of eight sub-samples of 50 fruits each, taken in separate traverses of the entire block. The reliability of this method of sampling has been tested previously by an examination of the degree of variation of any combination of sub-samples from the mean of the whole. The sample was taken after picking started, and all fruits were cut to determine the invisible infestation. Ripe drops from 20 sample trees were also examined, and the fruit infestation adjusted for this factor.

**Table 1.—Number of sample trees in the various orchards.**

| Orchard No. | Number of Trees in Orchard | Number of Sample Trees |
|---|---|---|
| 1 | 546 | 43 |
| 2 | 1,643 | 101 |
| 3 | 732 | 49 |
| 4 | 478 | 42 |
| 5 | 796 | 55 |
| 6 | 798 | 56 |
| 7 | 737 | 54 |
| 8 | 184 | 20 |

RESULTS.—A summarized statement of the observations on infestation of twigs and immature drops is given in table 2. The number of infested twigs and drops consists of the number of freshly wilted twigs collected plus the number of insects reared from the immature drops. The number of fruit moth larvae surviving parasitism was obtained by multiplying the number of infested twigs and drops by the percentage of fruit moth larvae not parasitized.

In table 3 infestation in twigs and immature drops is compared with moth survival, parasitism, and ripe fruit infestation.

Although ripe fruit infestation is caused largely by larvae of the third brood, those of the second brood are often present in considerable numbers. A value for parasitism in which the records for the first and second broods are combined seems to be the most satisfactory basis for comparison of parasitism with ripe fruit injury. As a measure of ripe fruit infestation the

**Table 2.—Infestation of peach twigs and immature drops and fruit moth larvae surviving parasitism in eight orchards in Burlington County, N. J., in 1938.***

| Collection Period | Average Number of Infested Twigs and Drops per Tree in Orchard— | | | | | | | | Average Number of Fruit Moth Larvae per Tree Surviving Parasitism in Orchard— | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| May 10–13 | 2.46 | .18 | 3.90 | 6.74 | 2.13 | 1.55 | 3.91 | 4.90 | .60 | .08 | 2.01 | 1.67 | .78 | .72 | 2.27 | 3.03 |
| May 16–19 | 4.35 | .50 | 11.18 | 21.68 | 3.89 | 2.11 | 7.43 | 7.10 | 1.81 | .28 | 6.38 | 10.51 | 1.38 | .87 | 4.64 | 4.11 |
| May 20–27 | 13.79 | .67 | 5.24 | 19.83 | 8.24 | 3.23 | 2.70 | 1.50 | 3.16 | .12 | 3.29 | 5.75 | 2.58 | .89 | .85 | .75 |
| May 28–June 3 | 3.56 | .42 | 3.45 | 7.87 | 4.60 | 2.77 | 2.59 | 4.35 | 1.09 | .12 | 1.65 | 2.90 | 1.15 | 1.69 | 1.37 | 2.86 |
| June 4–8 | .69 | .24 | 1.10 | 5.55 | 1.84 | 2.86 | 2.36 | 1.03 | .34 | .14 | .82 | 3.79 | .85 | 2.32 | 1.98 | .83 |
| June 9–14 | .47 | .15 | 1.50 | 4.74 | 1.36 | 1.63 | 1.93 | 1.75 | .33 | .15 | .85 | 3.70 | 1.15 | 1.44 | 1.57 | 1.08 |
| June 15–17 | .88 | 0.00 | .35 | 3.55 | 1.44 | .87 | 1.15 | 1.03 | .71 | 0.00 | .06 | 2.87 | 1.17 | .52 | .93 | .94 |
| June 18–23 | .81 | .05 | 4.86 | 3.03 | .85 | .36 | 4.00 | 3.75 | .05 | 0.00 | 1.37 | .89 | .59 | .13 | 1.14 | 1.28 |
| June 24–July 5 | 2.12 | .42 | 11.65 | 17.54 | 2.62 | 3.20 | 18.98 | 13.45 | .35 | .05 | 1.12 | 3.24 | .14 | .71 | 3.64 | 1.64 |
| July 5–12 | 12.60 | 1.11 | 8.09 | 16.49 | 4.13 | 5.32 | 14.79 | 8.17 | .43 | .04 | .82 | 2.00 | .66 | .85 | 8.54 | 5.67 |
| July 12–18 | 4.32 | .70 | 4.93 | 10.98 | 2.25 | 3.57 | 2.46 | 2.28 | 1.11 | .08 | .74 | 6.73 | 1.79 | 1.15 | 1.40 | 1.93 |
| July 19–26 | .98 | .30 | .75 | 1.05 | 1.35 | .70 | 1.07 | .40 | .16 | .05 | .17 | .21 | 1.10 | .26 | .45 | .40 |
| July 27–Aug. 1 | .30 | .07 | .31 | .48 | .51 | .25 | 1.67 | 1.47 | .20 | .07 | 0.00 | .30 | 0.00 | .25 | .91 | .67 |
| Aug. 2–6 | .30 | .03 | 1.02 | .64 | .36 | .12 | 2.59 | 2.70 | 0.00 | .01 | .46 | .32 | .36 | .12 | 1.89 | 1.53 |
| Aug. 9–11 | .51 | .20 | .45 | .24 | .82 | .11 | .98 | 2.23 | .17 | .02 | .29 | .14 | .38 | .11 | .59 | 1.63 |
| Total for season | 48.14 | 5.04 | 58.76 | 120.41 | 36.39 | 30.65 | 68.61 | 56.11 | 10.51 | 1.21 | 20.03 | 45.02 | 14.08 | 12.03 | 32.17 | 28.53 |

* The lines traversing the columns indicate the approximate beginning of second-brood infestation.

number of injured fruit per tree is considered a more reliable figure than the number per acre, since it contains less variation in the number of twigs and the number of fruits. Percentage infestation is influenced by great differences in the fruit load in the various orchards.

It may be observed from table 3, that the orchards having the highest first-brood parasitism also had the highest second-brood parasitization. It is also to be observed that the amount of parasitism was not appreciably affected by the size of the fruit moth population at the beginning of the season, as indicated by first-brood infestation, or by the population prevailing throughout the season of twig infestation, as indicated by combined first and second-brood infestation. Orchard 2, which had the second highest seasonal parasitization, had the lowest first-brood infestation and the lowest seasonal infestation. The effect of parasitism in reducing the moth population is apparent from a comparison of moth infestation and moth survival in first- and second-broods. The effect of parasitism is evident from a comparison of moth survival in the second-brood and moth survival in both first and second-broods. The degree of ripe fruit injury was largely dependent upon the degree to which parasitism reduced

**Table 3.—Summary of fruit moth infestation in peach twigs and drops, parasitization, moth survival, and ripe-fruit infestation in eight orchards in Burlington County, N. J.**

| Orchard No. | Infested Twigs and Drops, Average No. per Tree per Season | | Parasitization, Per Cent | | | Fruit Moth Surviving Parasitism, Average No. per Tree per Season | | Infestation of Ripe Fruit* | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | First Brood | Both Broods | First Brood | Second Brood | Both Broods | Second Brood | Both Broods | Per Cent | No. of Infested Fruit per Tree | No. of Infested Fruit per Acre |
| 1 | 25.32 | 48.14 | 71.1 | 86.1 | 78.2 | 3.18 | 10.51 | 5.0 | 19.6 | 1,495 |
| 2 | 2.16 | 5.04 | 58.8 | 88.9 | 75.9 | .32 | 1.21 | 3.1 | 12.6 | 1,301 |
| 3 | 26.72 | 58.76 | 43.6 | 84.5 | 65.9 | 4.97 | 20.03 | 16.5 | 22.9 | 2,507 |
| 4 | 72.99 | 120.41 | 56.0 | 72.7 | 62.6 | 12.94 | 45.02 | 21.4 | 93.4 | 7,283 |
| 5 | 24.35 | 36.39 | 60.4 | 63.2 | 61.3 | 4.43 | 14.08 | 3.7 | 8.3 | 708 |
| 6 | 15.38 | 30.65 | 44.2 | 77.4 | 60.8 | 3.45 | 12.03 | 17.6 | 40.0 | 4,476 |
| 7 | 22.07 | 68.61 | 38.3 | 60.1 | 53.1 | 18.56 | 32.17 | 32.0 | 117.4 | 8,806 |
| 8 | 21.66 | 56.11 | 37.2 | 37.2 | 49.5 | 14.75 | 28.35 | 28.8 | 100.4 | 5,822 |
| Average for orchards 1 and 2 | 13.74 | 26.59 | 64.9 | 87.5 | 77.1 | 1.75 | 5.86 | 4.0 | 16.1 | 1,398 |
| Average for orchards 3–6 | 34.86 | 61.55 | 51.0 | 74.4 | 62.6 | 6.45 | 22.79 | 14.8 | 41.1 | 3,743 |
| Average for orchards 7 and 8 | 21.86 | 62.36 | 37.8 | 58.6 | 51.3 | 16.65 | 30.25 | 30.4 | 108.9 | 7,314 |

* The fruit load ranged from 12,200 peaches per acre in Orchard 3 to 40,900 per acre in Orchard 4.

the moths surviving during the second-brood. The only outstanding exception was Orchard 5, in which low fruit infestation apparently was due to some factor other than parasitism.

When the data in table 3 are averaged according to degree of parasitization, the relationship between parasitization and ripe fruit injury is more apparent. Orchards 1 and 2 had an average seasonal parasitization of 77.1 per cent and a first-brood infestation of about 14 worms per tree, whereas orchards 7 and 8 had an average seasonal parasitization of 51.3 per cent and 22 worms per tree. In the two orchards with the highest parasitization the original infestation was barely maintained in the second brood whereas in the two orchards with lowest parasitization it was doubled.

Moth survival for both first and second broods was about 6 moths per tree for the orchards with highest parasitization as compared to about 30 per tree for the orchards with lowest parasitization. Moth survival for the second brood, which immediately precedes the brood producing the major portion of the ripe fruit infestation, was less than 2 per tree for the orchards having the highest parasitization compared to about 17 for the orchards having the lowest. The orchards with the lowest parasitism had more fruit injury than the orchards with the highest, the ratio being about 8 to 1 in percentage injury, 7 to 1 in injured fruit per tree, and 5 to 1 in injured fruit per acre. The four orchards having average parasitization of 62.6 per cent were intermediate in all values except that of the first-brood infestation.

These data indicate that high parasitism of the first two broods of moth larvae resulted in a correspondingly low infestation of ripe fruits and that the reduction in infestation was sufficient to be of definite economic importance.

SUMMARY.—An experiment was carried out on eight peach orchards in Burlington County, N. J., in 1938 to determine whether any definite correlation between parasitism of the oriental fruit moth larvae and subsequent infestation in ripe fruit could be detected. On representative trees detailed records were made of the first- and second-brood fruit moth population in infested twigs and immature drops and of the degree of parasitism. At harvest time counts were made of the ripe-fruit infestation in Elberta or varieties ripening at about the same time. In this series of orchards there was found to be a definite relationship between the larval parasitization and the infestation in ripe fruit. The records obtained ranged from an infestation of 4.0 per cent, or on an average 16.1 infested fruits per tree, in orchards having average seasonal parasitization of more than 70 per cent to infestation of 30.4 per cent, or 108.9 infested fruits per tree, in orchards having average seasonal parasitization of less than 60 per cent. The reduction of infestation in orchards having high parasitization was sufficient to be of important commercial value.—11-17-39.

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# Oriental Fruit Moth Larval Parasitism as Related to Infestation[1]

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The oriental fruit moth, *Grapholitha molesta* (Busck), which has been a pest on peaches in New Jersey for about twenty years, is attacked by a large number of species of parasitic insects in its egg, larval and pupal stages. Since 1924 damage to peaches by the fruit moth in New Jersey has been held down to a considerable

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extent by parasites. The most important of these appear to be species which attack the twig infesting larvae. In the surveys of parasites attacking twig-feeding larvae, the most important one in southern New Jersey has been found to be *Macrocentrus ancylivorus* Roh. and in northern New Jersey *Glypta rufiscutellaris* Cress. Population of the fruit moth reached such a low level from 1925 to 1933 that it was difficult to find an orchard suitable for carrying on insecticidal tests. Since there was practically no peach crop in 1934 and 1935 in New Jersey as a result of winter-killing, and since fruit moth damage had been negligible for several years before that, the project dealing with the control of this insect was dormant from 1932 to 1936 inclusive.

**Table 1.—Parasitism of oriental fruit moth larvae in four orchards in New Jersey in 1937.**

| Date Collected | No. of Moths | No. of Parasites M. ancylivorus | No. of Parasites Others | Per cent Parasitism |
|---|---|---|---|---|
| *Moorestown* | | | | |
| May 29 | 18 | 17 | 0 | |
| June 10 | 19 | 4 | 0 | |
| June 19 | 21 | 4 | 1 | |
| June 30 | 6 | 48 | 0 | |
| July 13 | 7 | 20 | 0 | |
| Totals | 71 | 93 | 1 | 57.0 |
| *Glassboro* | | | | |
| May 28 | 0 | 30 | 0 | |
| June 10 | 9 | 29 | 1 | |
| June 19 | 16 | 25 | 0 | |
| June 30 | 2 | 9 | 0 | |
| July 13 | 3 | 3 | 0 | |
| Totals | 30 | 96 | 1 | 76.3 |
| *Hammonton* | | | | |
| May 28 | 7 | 15 | 0 | |
| June 10 | 17 | 5 | 0 | |
| June 19 | 23 | 36 | 0 | |
| June 30 | 8 | 39 | 0 | |
| July 13 | 17 | 20 | 0 | |
| Totals | 72 | 115 | 0 | 61.5 |
| *Belvidere* | | | | |
| July 17 | 1 | 0 | 31* | 97.0 |

* Twenty-nine of these were *Glypta rufiscutellaris*.

There was a crop of peaches in New Jersey in 1936. During and after the peach harvesting season that year numerous complaints were received from peach growers concerning heavy losses caused by the fruit moth. There was so much interest in fruit moth control that the writer was asked to discuss the subject at the New Jersey State Horticultural Society meeting in December, 1936. Correspondence with workers in other states brought forth the information that in many sections in 1936 twig larval parasitism of the first two broods of the fruit moth was below what it had been in previous years. On the basis of this information the suggestion was offered that the cold winters preceding 1936 had upset the balance between the fruit moth and its natural enemies in some manner so as to allow the moth to build up in 1936 to damaging proportions.

It was proposed, therefore, to undertake surveys of larval parasitism in 1937 and succeeding years to determine whether or not fruit moth parasites were attacking twig-feeding larvae and if so, to what extent; also to learn whether the degree of larval parasitism could be used to determine the probable extent of worm damage by the third and fourth broods which attack the fruit primarily. It was reasoned that if the percentage of parasitism in first and second brood twig-feeding larvae was high enough there would be so few third and fourth brood individuals that damage to the ripening fruit would be negligible.

PARASITISM SURVEYS IN 1937.—A preliminary survey of parasitism of twig-feeding larvae of the oriental fruit moth was begun in 1937 about the last of May and continued to the middle of July. This covered the period of activity of first and second brood larvae. Twig-feeding larvae were collected at 10-day intervals. These were reared to maturity on green apples and the species of parasites and percentage of parasitism determined. One orchard in each of the peach-growing areas of Moorestown, Glassboro and Hammonton was thus surveyed. In addition, one sample of larvae was collected from an orchard at Belvidere in northern New Jersey on July 17. The results of this survey are set forth in table 1.

The data in table 1 show that in southern New Jersey during May, June, and July, 1939, parasites were active and destroyed a high percentage of twig-feeding larvae. From 57 to 76 per cent of all larvae reared to maturity were parasitized and practically all of the parasites proved to be *Macrocentrus ancylivorus*. From the collection made in northern New Jersey on July 17, 1937, 31 parasites and one fruit moth were reared. Twenty-nine of the parasites proved to be *Glypta rufiscutellaris*.

The results of the limited survey made

in 1937 showed that *Macrocentrus* in southern New Jersey and *Glypta* in northern New Jersey were present and active to a degree that compared favorably with other years when fruit moth damage was low. In the orchards surveyed fruit up to and including varieties ripening in the Elberta season showed less than 25 per cent total worm damage. Few complaints of wormy peaches were received following the 1937 peach harvesting period.

RESULTS OF SURVEYS IN 1938.—The survey of parasitism of twig-feeding larvae and fruit infestation determinations were expanded in 1938. In order to cover more orchards and to reach all the principal peach-growing sections of the state, the cooperation of county agents and individual growers was enlisted. These cooperators made larval collections at 10-day intervals from the last of May to the middle of July. Twigs containing larvae in all stages of development were mailed to the insectary at Glassboro where the insects were reared to maturity following the usual procedure.

In determining the fruit infestation from orchard to orchard it was decided to select the Elberta variety, or a variety ripening during the Elberta season, so that the fruit infestation figures would be comparable. These figures were obtained by selecting three to five trees near the center of the block and marking them before harvesting began. At each picking a representative sample of the fruit was examined to determine the visible injury. Following that procedure, some of the apparently sound fruits (usually 25 per cent) were sliced to determine the invisible injury. The combined figures gave the total fruit moth injury.

The results of the 1938 survey are given in table 2. In this table the orchards are arranged in the order of the highest to the lowest total larval parasitism. The second column of figures gives the total fruit infestation for the individual orchards. In the remaining columns the orchards are arranged in the order of highest to lowest second brood larval parasitism with the corresponding fruit infestation figures for each orchard in the last column.

The data in table 2 show that the combined parasitism of first and second brood twig-feeding larvae ranged from 5.5 per cent to 76.6 per cent. In 13 of the 17 orchards the parasitism for the two broods was 50 per cent or more. On second brood alone parasitism ranged from 45.5 per cent to 100 per cent with all the orchards but two showing 70 per cent parasitism or higher. It might be explained at this point that in four or five of the orchards showing 100 per cent, or nearly 100 per cent, parasitism on second brood, only a few insects were reared from the second brood twig collections and all of these were parasites. Had a larger sample been collected the percentage parasitism might have been lower.

**Table 2.—Oriental fruit moth larval parasitism and fruit infestation found in 17 orchards in New Jersey in 1938.**

| Orchard No. | 1st & 2nd Brood Parasitism | Fruit Infestation | Orchard No. | 2nd Brood Parasitism | Fruit Infestation |
|---|---|---|---|---|---|
| 1 | 76.6% | 23.8% | 17 | 100.0% | 33.9% |
| 2 | 75.0 | 19.3 | 9 | 100.0 | 16.5 |
| 3 | 74.7 | 18.8 | 7 | 100.0 | 17.3 |
| 4 | 74.4 | 25.0 | 13 | 98.8 | 20.8 |
| 5 | 74.4 | 8.5 | 11 | 97.7 | 6.2 |
| 6 | 70.0 | 12.8 | 4 | 96.1 | 8.5 |
| 7 | 66.6 | 17.3 | 1 | 94.6 | 23.8 |
| 8 | 66.2 | 34.2 | 14 | 91.7 | 20.3 |
| 9 | 66.0 | 16.5 | 2 | 91.3 | 19.3 |
| 10 | 65.5 | 18.5 | 3 | 91.2 | 18.8 |
| 11 | 54.6 | 6.2 | 6 | 90.0 | 12.8 |
| 12 | 51.3 | 14.6 | 8 | 86.0 | 34.2 |
| 13 | 50.0 | 20.8 | 10 | 82.6 | 18.5 |
| 14 | 46.8 | 20.3 | 4 | 81.7 | 25.0 |
| 15 | 34.3 | 96.4 | 12 | 70.0 | 14.6 |
| 16 | 33.3 | 35.9 | 16 | 58.6 | 35.9 |
| 17 | 5.5 | 33.9 | 15 | 45.4 | 96.4 |

As in 1937, the principal parasite in the southern New Jersey area was *Macrocentrus ancylivorus* whereas in northern New Jersey it was *Glypta*.

An examination of the fruit infestation figures in table 2 will show that the total fruit infestation (visible and invisible) on a late ripening variety (Elberta season) was less than 25 per cent in 12 of the 17 orchards. If we compare the total parasitism of the first two broods with the fruit infestation, or if we compare second brood parasitism alone with the fruit infestation, there is no clear cut correlation. There is a rough correlation, however, because orchards 15, 16, and 17 with the lowest total parasitism have the highest fruit infestation. Orchards 1 and 8, with relatively high parasitism figures, had light crops. This factor is known to affect the percentage fruit infestation. If we examine the second brood parasitism in relation to fruit infestation we find orchards 15 and 16 show low parasitism with high fruit infestation. Orchard 17, on the other hand, showed 100 per cent para-

sitism of the second brood. As already pointed out, this orchard was one of several where only a few individuals, all of which proved to be parasites, were reared from second brood material.

RESULTS OF SURVEYS IN 1939.—At the end of the 1938 season it was found that the idea of including a large number of orchards in the survey was sound, but that depending on growers to collect the material was questionable. There was considerable variation in the ability of growers to find twigs containing larvae. Many collections sent in contained a preponderance of twigs from which larvae had emerged. Then, too, some growers were more negligent and did not send samples at the proper intervals. The net result of our experience with growers was the decision to limit the orchards in the 1939 survey to the number that could be collected by the writer and assistants and by several county agricultural agents. By following this procedure all the sampling in a given area was done by the same individual.

**Table 3.—Oriental fruit moth larval parasitism and fruit infestation found in 22 orchards in New Jersey in 1939.**

| Orchard No. | 1st & 2nd Brood Parasitism | Fruit Infestation | Orchard No. | 2nd Brood Parasitism | Fruit Infestation |
|---|---|---|---|---|---|
| 1 | 76.3% | 23.4% | 20 | 100.0% | 14.7% |
| 2 | 72.8 | 7.6 | 2 | 93.4 | 7.6 |
| 3 | 66.6 | 37.5 | 22 | 92.0 | 39.6 |
| 4 | 65.8 | 28.6 | 4 | 89.0 | 28.6 |
| 5 | 64.2 | 11.0 | 1 | 87.0 | 23.4 |
| 6 | 63.5 | 25.9 | 7 | 86.0 | 8.0 |
| 7 | 55.3 | 8.0 | 6 | 84.0 | 25.9 |
| 8 | 53.7 | 12.7 | 5 | 83.0 | 11.0 |
| 9 | 52.4 | 24.5 | 12 | 82.0 | 1.5 |
| 10 | 51.3 | 18.5 | 3 | 77.4 | 37.5 |
| 11 | 47.2 | 62.6 | 17 | 75.0 | 8.9 |
| 12 | 46.9 | 1.5 | 15 | 68.0 | 9.3 |
| 13 | 45.4 | 12.8 | 16 | 66.6 | 10.4 |
| 14 | 45.4 | 31.1 | 11 | 66.1 | 62.6 |
| 15 | 44.7 | 9.3 | 10 | 65.0 | 18.5 |
| 16 | 44.1 | 10.4 | 8 | 63.2 | 12.7 |
| 17 | 41.0 | 8.9 | 19 | 61.7 | 16.1 |
| 18 | 39.4 | 13.1 | 9 | 61.1 | 24.5 |
| 19 | 38.4 | 16.1 | 14 | 57.6 | 31.1 |
| 20 | 28.8 | 14.7 | 18 | 50.4 | 13.1 |
| 21 | 27.7 | 32.6 | 21 | 47.1 | 23.6 |
| 22 | 26.6 | 39.6 | 13 | 42.1 | 12.8 |

Twig-feeding larvae were collected and reared to maturity and fruit infestation counts made on Elberta, or a variety ripening near Elberta, in 22 orchards in 10 counties scattered throughout the state. The usual 10-day interval between collection dates was followed, beginning the last of May and continuing to the middle of July. The results of the survey are set forth in table 3. The same arrangement of orchards from highest to the lowest total parasitism and highest to the lowest second brood parasitism, followed by the percentage fruit infestation, is followed in table 3 as was followed in table 2.

The data in table 3 show that fruit moth larval parasitism in 22 New Jersey orchards in 1939 ranged from 26.6 per cent to 76.3 per cent for larvae collected from both first and second brood. Approximately half of the orchards showed 50 per cent or more of all the larvae parasitized. The figures for second brood only show 20 out of 22 orchards with 50 per cent parasitism or more. In 1939, as in 1937 and 1938, *Macrocentrus ancylivorus* was the most important parasite reared in southern New Jersey with *Glypta* again in the lead as the most important parasite in the northern section. Taking the orchards as a whole, fruit infestation was moderate for the third successive year. Only seven of the 22 orchards showed more than 25 per cent visible and invisible injury on Elberta or varieties ripening during the Elberta season.

Comparing the fruit infestation figures with either total percentage parasitism or second brood parasitism, we again find no definite correlation. For example, orchard 3 which has the third highest total parasitism also has the third highest fruit infestation. To take another example, orchard 4 with the fourth highest total parasitism and the fourth highest second brood parasitism has the fifth highest fruit infestation. On the other hand, orchards 12, 13, 15, 16 and 17 are orchards where both total and second brood parasitism were comparatively low, yet their fruit infestation figures are among the lowest.

ARRANGEMENT OF VARIETIES AFFECTS FRUIT INFESTATION.—At first the reason for the differences in fruit infestation from orchard to orchard was not apparent. Differences in time of ripening were ruled out because the same variety, or a variety ripening in the same period, was used in making the counts in each orchard. Differences in the crop load from orchard to orchard were considered and the effect of this has already been referred to but was not sufficient to serve as the only explanation. In 1938, and to a greater extent in 1939, it was observed that the type of planting had a bearing on the degree of fruit infestation. In order to examine this

idea more critically the orchards in the 1939 survey are arranged in three groups in table 4. In the first group are orchards where the count variety was interplanted with early and midseason ripening varieties and/or apples. In the second group are placed the orchards which are semi-interplanted or where the nature of the planting has not been learned. In the third group are placed the orchards where the count variety is known to be planted along with other varieties ripening about the same time or later.

A study of the orchard arrangement in table 4 will show that those orchards where the count variety was interplanted with earlier ripening peaches or apples showed the highest fruit infestation. Conversely, those orchards showing the lowest fruit infestation fall in the group planted entirely to late varieties. The location of the orchard in the state appears to have no bearing on the degree of infestation. Orchards from southern New Jersey and from northern New Jersey are to be found in each group as shown by the list of counties in which the various orchards were located.

**Table 4.—Relationship of varietal planting arrangement to oriental fruit moth infestation on peaches.**

| Orchard Number | County | Nature of Planting | Fruit Infestation |
|---|---|---|---|
| 11 | Somerset | Interplanted with early and midseason ripening peaches or apples. | 62.6% |
| 22 | Cumberland | | 39.6 |
| 3 | Burlington | | 37.5 |
| 4 | Burlington | | 28.6 |
| 21 | Warren | | 32.6 |
| 14 | Camden | | 31.1 |
| 6 | Cumberland | Semi-interplanted or unknown. | 25.9 |
| 9 | Camden | | 24.5 |
| 1 | Hunterdon | | 23.4 |
| 10 | Burlington | | 18.5 |
| 19 | Bergen | | 16.1 |
| 20 | Cumberland | | 14.7 |
| 18 | Bergen | Solid planting of the late varieties. | 13.1 |
| 13 | Camden | | 12.8 |
| 8 | Gloucester | | 12.7 |
| 5 | Hunterdon | | 11.0 |
| 16 | Gloucester | | 10.4 |
| 15 | Gloucester | | 9.3 |
| 17 | Camden | | 8.9 |
| 7 | Burlington | | 8.0 |
| 2 | Atlantic | | 7.6 |
| 12 | Morris | | 1.5 |

SUMMARY AND CONCLUSIONS.—A three-year survey of the parasitism of twig-feeding larvae and fruit infestation was made in a number of New Jersey orchards from 1937 to 1939 inclusive. A high degree of parasitism of the first two broods of larvae was found in the majority of orchards in each of the three years. In southern New Jersey the principal parasite found was *Macrocentrus ancylivorus* and in northern New Jersey *Glypta rufiscutellaris*. Fruit infestation in each of the three years was light to moderate on varieties ripening during the Elberta season in the majority of the orchards. No strict correlation was found between either percentage total parasitism or second brood parasitism and percentage fruit infestation. A correlation was found between the nature of the planting and the percentage fruit infestation. Orchards in which late ripening varieties were interplanted with early and midseason ripening varieties of peaches showed high fruit infestation counts on the late ripening varieties. Blocks planted solid to late ripening varieties showed the lowest fruit infestation counts.

The results reported, if substantiated by additional observations, can be applied to advantage by peach growers in arranging future plantings of peaches. The interplanting of early- mid- and late-season varieties of peaches should be avoided as well as the interplanting of peaches and apples.—11-16-39.

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# A Plot Arrangement for Timing the Applications in a Control Program[1]

HUGH GLASGOW, *Chief in Research, New York State Agricultural Experiment Station, Geneva, N. Y.*

In the working out of any control program where the use of chemical treatments is involved the first consideration is naturally the singling out of the most effective insecticide to use. Once this has been accomplished, however, we are faced squarely with the problem of timing. Naturally any suitable insecticide should be expected to give satisfactory control if

[1] Approved December 14, 1939, by the Director of the New York State Agricultural Experiment Station for publication as Journal Paper 357.

the applications are thoroughly made and these can be repeated at frequent intervals throughout the active period of the insect. When we consider the narrow margin on which most agricultural crops are produced it is obvious that with but few exceptions the cost of a control program must be kept within rather narrow limits, for if this is not done an otherwise highly satisfactory schedule may prove of little or no practical value in the hands of the grower.

This means that if a control schedule is to be acceptable to the grower every effort must be made by those responsible for working it out to concentrate on those applications that can be expected to give the greatest degree of control and to eliminate so far as possible all operations that may be of questionable value. In order to accomplish this with a minimum loss in time and effort we have adopted as a more or less routine procedure in our insecticide testing program a simple method of plot arrangement that we developed a number of years ago in connection with some of our studies on cabbage root maggot control.[2]

Briefly, the method to be described provides for a simple arrangement of plots, from 3 to 21 or more, the exact number depending on the probable complexity of the control program that is being considered. These plots are then divided into groups that decrease progressively in number until there is but a single plot in the final section. The example that is given here to illustrate this method (Table 1) is made up of a total of 21 plots, exclusive of the checks, providing for six successive applications of the particular insecticide to be tested. It will be seen from a study of this diagram that the first application is made to all six plots in section 1. At the time the second application is to be made, only the last five plots in section 1 and all five plots in section 2 are treated. When the third application is made only the last four plots in section 1 and the last four in section 2 are treated, while all four plots in section 3 are treated for the first time. This procedure is followed consistently throughout the season, one new plot being omitted from each of the sections already treated and one entire new section being added to the treated series at each interval until at the end of the fifth period only the last plot in each of the six series receives an application.

**Table 1.—Diagram showing arrangement of plots and sequence of applications in a typical 21-plot timing experiment.**

| SECTION | 1 | | | | | | 2 | | | | | 3 | | | | 4 | | | 5 | | 6 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Plot | 1, | 2, | 3, | 4, | 5, | 6 | 1, | 2, | 3, | 4, | 5 | 1, | 2, | 3, | 4 | 1, | 2, | 3 | 1, | 2 | 1 |
| June 1 | x | x | x | x | x | x | | | | | | | | | | | | | | | |
| June 8 | | x | x | x | x | x | x | x | x | x | x | | | | | | | | | | |
| June 15 | | | x | x | x | x | | x | x | x | x | x | x | x | x | | | | | | |
| June 22 | | | | x | x | x | | | x | x | x | | x | x | x | x | x | x | | | |
| June 29 | | | | | x | x | | | | x | x | | | x | x | | x | x | x | x | |
| July 6 | | | | | | x | | | | | x | | | | x | | | x | | x | x |

In the above diagram the check marks serve to indicate the time of making the various applications as well as the number of applications received by each plot.

A glance at the diagram (Table 1) illustrating the operation of such an experimental setup will perhaps make the general procedure clearer than any description that can be given.

Such a series of tests carried out consistently, and of course replicated if dealing with a pest that is not certain to be uniformly distributed throughout a planting, should go far towards providing an accurate, concise answer to almost any question that can be raised bearing on the problem of timing.

The method adapts itself readily to any intervals that may be chosen for spacing the applications, arbitrary dates as in the example given, or, as in certain fruit schedules, irregular intervals based on the developmental stages of the particular host plant to be treated.

In order to make the description of this method a little clearer and perhaps more helpful an example of one typical 21-plot

[2] JOUR. ECON. ENT. Vol. 16, pp. 68–73. 1923.

**Table 2.—Timing experiment as illustrated by results on onion maggot control through the use of lubricating oil spray.**

| Number of Applications | Sequence of Applications (by Weeks) and Yield on Basis of Bushels per Acre | | | | | | |
|---|---|---|---|---|---|---|---|
| | First | Second | Third | Fourth | Fifth | Sixth | Check |
| 1 | 240 | 426 | 82 | 67 | 19 | 24 | 42 |
| 2 | 540 | 379 | 100 | 33 | 16 | | |
| 3 | 765 | 522 | 201 | 24 | | | |
| 4 | 646 | 536 | 216 | | | | |
| 5 | 768 | 479 | | | | | |
| 6 | 687 | | | | | | |

timing experiment is included, figures 1 and 2, and table 2 serving to illustrate this particular test. The primary object of this experiment was to demonstrate the place of the lubricating oil spray in onion maggot control and to establish such points as the correct time to start spraying operations, the number of treatments probably necessary to insure satisfactory commercial control, and the degree of control that might be expected from deferred applications. It is given here not as an example of onion maggot control but merely to serve as an illustration of the method under discussion.

FIG. 1.—Timing experiment, onion maggot control with lubricating oil sprays. Block of 27 rows, each 100 feet long, in middle of field.

In this instance the 21 plots consisted of single rows since the infestation in this field had always been heavy and surprisingly uniform. Obviously it would have been better to have had at least three rows in each plot to guard against any possible influence of adjacent treated or untreated rows. Also a test block of this sort might well be replicated several times, but owing to the uniform infestation that was expected and to the physical limitations encountered, the test was confined to the single block, as described.

The experimental block was located in the center of a planting that received a routine application of four sprays for control of the maggot. The rows in the test block were 100 feet long and, as will be seen by a glance at figure 1, the 21 rows making up the treated area were bounded on either side by three check rows which

received no treatment at all. The schedule of treatments in this experiment was started at a time when perhaps 75 per cent of the onion plants had pulled the tips of the seed leaves free and were beginning to straighten up. This initial application was then repeated at regular intervals of approximately one week, as has already been described, until six treatments had been made.

Figure 1 shows the appearance of this test block after the tops had withered and immediately before harvesting. Even at this time, and before the yield records were secured, differences in the various plots were quite apparent. For example, even in the photographic record (Fig. 1) it is apparent that in section 1 there is a progressive improvement in the stand as we pass from row 1 to row 3, while beyond this, to the eye at least, there is little or no difference. The contrast between rows 6 and 7, representing as they do the break between section 1, receiving the earliest treatment, and section 2, where treatment was started one week later, is sharply defined. The control in section 2 is apparently less complete than in section 1, suggesting a loss in efficiency as a result of deferring treatment even for a week. When we come to the division between section 2 and section 3 which falls between row 11 and row 12, the contrast is still more pronounced; while beyond section 3, of which row 15 is the last, there appears to be little if any control as a result of these deferred treatments, the stand in sections 4, 5 and 6 appearing, if anything, more ragged than that in the untreated checks.

The harvesting record for this series of tests is shown in figure 2. Here the contrasts between the various sections of the experimental block as well as between the individual rows are even more pronounced than appears in figure 1, although the same general trend that was suggested from a study of figure 1 is maintained. The progressive improvement in yield as well as in the relation of sound to maggot-injured onions as one passes from row 1 to row 3 in section 1 is very apparent as is also the contrast shown between the other sections of the experiment. It should be noted here that in figure 2 the maggot-injured onions appear for each row in the upper crate.

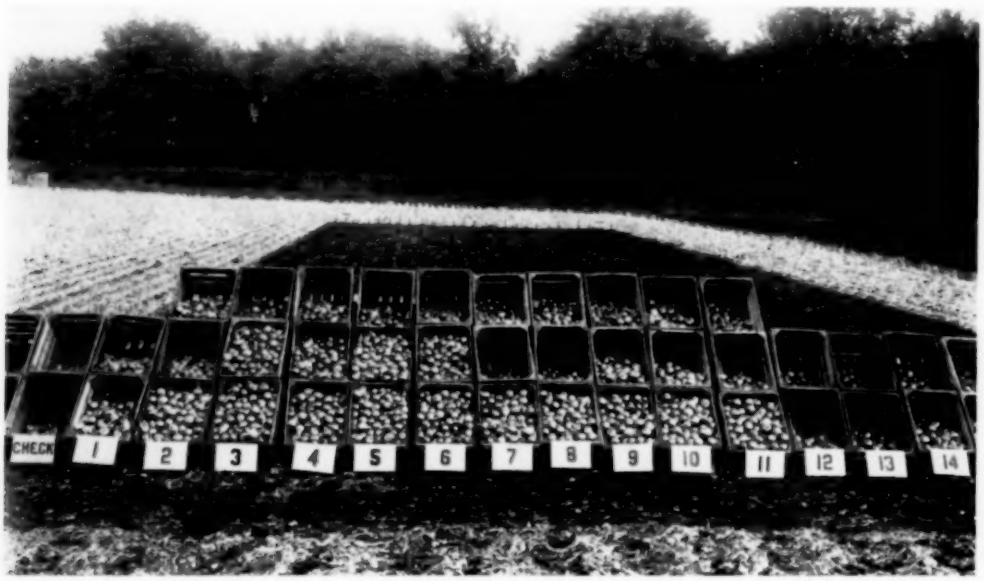


FIG. 2.—Yield from timing experiment shown in figure 1. Upper crate contains onions injured by maggots in each row.

In table 2 will be found the yield records for the various units in this experiment. Here the differences in yield resulting from the variously timed applications, suggested in figures 1 and 2, are even more sharply defined. There is seen to be a consistent, progressive increase in yield following the three early applications in

section 1. Beyond this the differences in this particular group do not appear clear-cut and give the impression that perhaps little would be gained by continuing the treatments in this series much beyond three. In the second series the differences in yield would seem to indicate that a falling off in control might be looked for as a result of delaying the first treatment for even one week, although for some reason the yield from the first plot in the second series appears to be abnormally high. If it were not for the consistently downward trend in all the other rows in this section the above inference would hardly be warranted. While the differences in yield between the four plots in section 3 and the check would doubtless more than warrant the expense of the treatments represented it is possible that such deferred treatments might be of questionable value under some conditions, and beyond this point it is very evident that little or nothing in the way of control could be expected when treatments were started after the third interval. The contrasts in yield that are so apparent in a comparison of most of the rows in section 1 with the corresponding rows of section 2 suggest that perhaps the entire program should have been started somewhat earlier than it was, particularly since the treatments started later in the season were found to be of so little value.

SUMMARY.—The results of this particular experiment are presented, not for any bearing they may have on onion maggot control, but merely to illustrate the procedure followed and the type of information that may be expected from a timing experiment of this character. We have carried through this general program repeatedly in dealing with problems such as those presented by the cabbage root maggot, the onion maggot, the pea aphid, and others. The method has also been applied effectively in connection with certain fruit problems. Where an infestation is heavy and is evenly distributed throughout a planting, as in the example given, the application of this method is relatively simple. Its use becomes more involved, however, when dealing with an infestation that is likely to be somewhat erratic.

While at first the manipulation of such a series of plots may appear a needlessly complicated and burdensome procedure, in reality the plan is quite simple and easy to carry out. In general we have found this method exceedingly helpful in the working out of a logical and well rounded control schedule, and we feel sure that others will find it equally useful if they are willing to give it a careful trial.—11-16-39.

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# The Relative Effects on Insect Metabolism of Temperatures Derived from Constant and Variable Sources[1]

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To any student of the effect of temperature upon insect metabolism the relation between variable and constant temperatures is an interesting subject. On the one hand, temperatures influencing insect metabolism in a state of nature are variable, while on the other hand, actual measurement of temperature effects on insect metabolism appear to demand the use of constant temperatures. What is the relation that exists between metabolic effect produced by variable and by constant temperatures?

Shelford (1927) set forth as a part of the results of his study on climate and codling moth the following conclusions: "All available data on pupae, taken together, indicate that length of the stage under variable temperatures is approximately 7 per cent shorter than under constant temperatures, although no experiments were especially designed to verify this difference. Such experiments, to give results comparable with those under actual weather conditions, would have to include temperatures outside the straight-line limits. The crucial experiments . . . , with temperatures varying slowly within the straight-line limits, showed the same acceleration as the weather conditions.

"The effect of normal daily variations of out-door temperatures, when corrected to the velocity curve and compared to the constant-temperature results, amounts to

[1] Paper of the Journal Series, New Jersey Agricultural Experiment Station, Department of Entomology.

7 to 8 per cent more rapid development than that under constant temperatures, for the pupae. The egg data suggest a difference of about 7 per cent, and the larval data about 8 per cent. In every stage, development is more rapid under the normal out-door variations."

Peairs (1927) as a result of a study on the effect of temperature on the metabolism, principally of the blow fly, reaches the following conclusions: "Tables 26 and 27 show a similar acceleration when temperature variations were provided within the constant temperature incubators by moving the insects from one to another. Here again the variation is not usually greater than the deviation from the constant temperatures but it is without exception a minus variation. The significant fact about the variation in these tables is similar to that observed under the outdoor conditions; that is, that the variation from the calculated thermal constant is always a minus variation." In discussing this and other conclusions, Peairs says: "Why a stimulation should occur from variation in temperature is not clear. A speculative reason might be that the protoplasm of these organisms is adapted to variable conditions and that variable temperatures constitute a normal environment while constant temperatures are abnormal and so retard development. This would interpret the difference in rate as a retardation due to constant temperatures rather than as an effect of the stimulation from variation of the temperature."

Headlee (1929) published the results of a study of the relative effect of a diurnal variation and a constant run at the average thereof on codling moth, starting with overwintered larvae April 15, 1928. The results are set forth in table 1.

This table shows that whereas 21 days were required in the variable for maximum emergence to take place the same stage of development was reached in the constant temperature in 13 days. The lot in the screen insectary, under outdoor conditions, required 23 days for maximum emergence. The effect of these conditions upon the percentage of larvae producing adult moths was approximately the same in each case but in the constant only 56 per cent emerged as compared to 66 per cent in the variable and 64 per cent under outdoor conditions. Naturally, the least temperature accumulations were required to bring about maximum emergence in the constant, more were necessary in the variable and still more were necessary under outdoor conditions.

**Table 1.—Relative effects of constant versus variable temperatures on codling moth emergence.***

| Temperature | | Days to Maximum Emergence | | Larvae Developing into Moths | | Accumulated Day Degrees, Effective Temperature | |
|---|---|---|---|---|---|---|---|
| Constant | Variable | Constant | Variable | Constant | Variable | Constant | Variable |
| 63° | 50° to 76° | 13 | 21 | 56% | 66% | 417.25 | 521.25 |
| Screen Insectary | | | 23 | | 64 | | |

* Temperatures indicated in this paper are Fahrenheit.

Beginning in November, 1938, further study of this question of the relative effects of constant versus variable temperatures became practicable. The insect used was a tropical and sub-tropical mosquito, *Aedes aegypti*. Two insulated boxes were placed in a large refrigerator running constantly between 40 and 45 degrees. Resistance-wire heaters under thermostatic control were utilized to raise the temperature of each box to the desired point. The thermostat for the constant temperature box consisted of a bi-metallic strip and a screw point electrode. By manually setting the screw point electrode the box could be so set that the heater worked to the point where proper temperature was maintained. The thermostat for the variable temperature box consisted of a bi-metallic strip and an electrode under clockwork control. The drive-wheel to which the electrode was attached revolved on clockwork stimulus once in 24 hours, reaching a maximum high at about two o'clock in the afternoon and a minimum low at about two o'clock in the morning. This mechanism has been eminently satisfactory.

The entire set of experiments was run in darkness and inasmuch as the mos-

quito larvae and pupae lived in water no variation of humidity was possible. The water used was distilled, charged with measured amounts of brewer's yeast. The sole variant resided in the temperature. Three series were run. In the first series the controlled variable covered a range of from 50 degrees to 80 degrees and the constant ran at the mean of the variable or 65 degrees. The second series showed a variable range of from 60 degrees to 90 degrees and the constant ran at the mean of this range, or 75 degrees. The third series covered the variable range of 70 degrees to 100 degrees with a constant running at the mean of this variable or 85 degrees. In each individual experiment the same number of newly hatched larvae were placed in each of the two boxes. The machines were kept running and the data taken until the experiment was completed. This experiment was then followed by another and so on until the entire series was completed.

Two criteria of results were utilized. The first was the length of time required for the insects to develop from newly hatched larvae to maximum emergence as adults. The second was the percentage of the total number of larvae that succeeded in developing into adult mosquitoes. The results are set forth in table 2.

Table 2.—Relative effects of constant versus variable temperatures on the mosquito, *Aedes aegypti*.

| Temperature | | Days from Newly Hatched to Maximum Emergence | | Per Cent, Larvae Reaching Adult Stage | | Accumulated Day Degrees Effective Temperature | |
|---|---|---|---|---|---|---|---|
| Constant | Variable | Constant | Variable | Constant | Variable | Constant | Variable |
| 65° | 50° to 80° | 24.5 | 23 | 17.3 | 32.0 | 367.5 | 345.0 |
| 75° | 60° to 90° | 13.0 | 20 | 25.2 | 60.0 | 325.0 | 500.0 |
| 85° | 70° to 100° | 10.0 | 28 | 74.0 | 2.1 | 350.0 | 980.0 |

An equal or somewhat longer time was required in the first series for development under constant conditions, the constant requiring 24.5 days and the variable 23 days. In the second series 13 days were required to produce maximum emergence in the constant and 20 days in the variable. In the third series 10 days were required to produce maximum emergence in the constant and 28 days in the variable.

Now when we turn to the effect of these temperature conditions on the percentage of larvae that were able to develop into adults, we find in the first series 17.3 per cent coming through in the constant as compared to 32 per cent in the variable, in the second series 25.2 per cent in the constant as compared to 60 per cent in the variable and in the third series 74 per cent in the constant as compared to 2.1 per cent in the variable.

The speed of development in the first series is a little greater in the variable, less in the second series and much less in the third series.

The accumulative temperatures correspond naturally to the length of period required for the development to take place.

When the results of different sets of experiments appear to disagree a situation is established in which the reason for the differences should be sought. Shelford, in the above mentioned piece of work, uncovered what may be the basic reason when he said, "Such experiments to give results comparable with those under actual weather conditions would have to include temperatures outside the straight-line limits." Shelford is apparently referring in this passage to the sigmoid curve of growth which, by the way, is also the characteristic curve of reaction of insects to external factors of the insect environment. The straight-line section referred to is that portion of the curve which is a straight-line and lies between the foot curve and the top curve of different gradients. The foot curve represents a region of retardation due to low temperatures and the top curve represents a region of retardation due to high temperatures. If the variable range under examination goes over into the foot curve or into the top curve the speed of metabolism is likely to be reduced and more time required to complete the same metabolic changes in the variable than would be necessary to complete the same changes in the constant. If the constant is too close either to the region of the foot curve or of the top

curve, retardation is likely to take place.

It appears, therefore, that the relation of the metabolic effect of variable temperature and constant temperature is dependent upon where, in the temperature gamut of the particular insect or stage concerned, this variable and this constant lies. The next step in an investigation of this sort is to accumulate data in the hope of working out a reliable ratio.—11-16-39.

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# Control of the Leaf Roller, *Platynota flavedana* Clem. on Roses[1]

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During the fall and winter of 1938–39 an infestation of lepidopterous larvae was found doing considerable damage to the foliage and bloom of greenhouse roses at Cranbury. From the markings of the larva it appeared that two species of leaf rollers were involved. The larvae of one species were about $\frac{5}{8}$ inch long when fully grown, slightly greenish in color and had a black head, pronotal shield and anal shield. They resembled the description of the larvae of the rose bud worm, *Olethreutes nimbatana* Clem.[2] The larvae of the other species were from five eighths to three fourths of an inch long when fully grown, somewhat greenish brown in general body color, with a brown head, pronotal shield and anal shield. This species was identified from adults reared from larvae as *Platynota flavedana* Clem. The identification was made by August Busck of the Bureau of Entomology and Plant Quarantine, Division of Insect Identification, Washington, D. C.

Soon after control measures were started in the greenhouse the larvae with the black head, pronotal shield and anal shield disappeared. Adults were not reared from these larvae and their identification as *Olethreutes nimbatana* was not verified.

HISTORY OF THE LEAF ROLLER.—*Platynota flavedana* was described by Clemens in the *Proceedings* of the Academy of Natural Science of Philadelphia for 1860, page 348, and is listed by Dyar (1902). Forbes (1905) mentions it as occurring in Illinois, and Smith (1910) states that it occurs throughout New Jersey and that the larva is a general feeder. Forbes (1923), states that it is common and generally distributed and that the larva is a general feeder. Bottimer (1926) states: 'Three adults were obtained during the first season. One moth emerged August 12 from a pupa collected August 7 in loosely tied leaves of an undetermined plant at Liberty. Larvae were found webbing together and feeding upon the yellow ray flowers of *Helianthus* sp. at Smith Point, September 14. One of these pupated in the loosely webbed ray flowers September 17 and the adult emerged September 26. A larva of *P. flavedana* was taken with larvae of *P. rostrana* (Walker) and *Sparganothis sulfureana* (Clemens) on *Eupatorium compositifolium* Walker at Smith Point, September 14. This specimen pupated September 19 and the adult emerged September 26.

No references other than those mentioned have been found in the literature regarding *Platynota flavedana*. Information on its life history, habits and food plants is very meager and until its occurrence at Cranbury it had not been reported as a pest of roses.

OTHER SPECIES OF THE GENUS.—*Platynota stultana* Walsingham has been recorded as a pest of roses in the eastern United States and of oranges in California. Busck (1933) states that *Platynota*

[1] Paper of the Journal Series, New Jersey Agricultural Experiment Station, Department of Entomology.

[2] *Hedia ochroleucana* Hbn. in McDunnough Check List. Ed.

*chiquitana*, Barnes and Busck, recorded as a pest of citrus and several other plants in California, is a synonym of *P. stultana* Wlsm.

McGregor (1934) describes injury caused by *P. stultana* to green oranges. Bourne (1936) collected the adults in a rose greenhouse at Revere, Mass. Eight hundred and one moths were collected in two *Electrocutor* light traps between April 15 and May 29, 1935. He does not give any information on its life history, habits or injury to roses.

Observations on the life history of *Platynota stultana* were made in 1935 by Nelson (1936) who gives the following data. Lengths of the various stages in days are as follows: egg, minimum 8, maximum 11, average 9; larva, minimum 19, maximum 47, average 31.1; pupa, minimum 7, maximum 11, average 9; egg to adult, minimum 37, maximum 64, average 48.6. Studies on the egg laying habits of 12 mated females showed that one female oviposited on the second day after emergence, 8 on the third day, 9 on the fourth day and all on the fifth day; that 50.86 per cent of the eggs were laid during the first four days of adult life, and 92.68 per cent during the first eight days. The largest number of eggs laid by a female was 498, the smallest 92, and the average for the 12 females was 293. The heaviest oviposition was on the third, fourth and fifth days.

The somewhat detailed observations on the life history and oviposition of *P. stultana* by Nelson are given because this species feeds on roses, because it is closely related to *P. flavedana*, and because of the lack of any information on the life history and habits of *P. flavedana* or previous records of its feeding on roses.

No studies on the life history of *Platynota flavedana* were made at Cranbury. Observations made during the progress of the control practices would indicate that in April and May the length of the egg stage was about 10 days and the length of the egg and larval stage from four to five weeks. Fumigation was started on April 10 and very few larvae were found after May 20, and these were all full grown or nearly full grown. Since the nicotine fumigation killed only the adults, the collection of larvae would indicate that the life cycle from egg to adult occupied approximately 40 days.

INJURY TO ROSES BY *Platynota flavedana*.—Nelson (1936) and Bourne (1936) do not give any information on the nature of this injury. Observations made at Cranbury on *Platynota flavedana* were as follows: Usually only a few infested leaves or tips were found on a single plant; when the infestation was heavy, as many as eight to 12 larvae were found on a plant containing half a dozen leaders. This would indicate that the eggs were not laid in large batches.

The very young larvae first fed on the petiole of a young rose leaflet, cutting the petiole so that the leaflet wilted. The larva then folded and webbed this small leaflet, often not more than one fourth to one third grown, and fed for a time on the upper, and inside, surface. After several days, when the leaflet had dried and become unpalatable, the larva moved to another one, usually somewhat larger, cut the petiole, folded and webbed the leaflet together and again fed on the inside of the fold. After the larvae are about one third to one half grown they do not cut the petiole but are able to web the leaflets and leaves together and feed on the inside of the cluster. Some feeding occurs on the tender terminal stems. The most of the damage, however, is caused by the larger larvae feeding on the buds. In house No. 2, before fumigation was started on April 28, from 20 to 25 per cent of the buds were injured. The larvae of *Platynota flavedana* are considerably better protected by folded leaves than are most other leaf rollers encountered on greenhouse roses.

CONTROL METHODS.—When the infestation was first noticed in the greenhouses, it was recommended that a pyrethrum and soap spray be used to kill the larvae, since this had proven very effective in other rose houses against larvae of the oblique banded leaf roller, *Cacoecia rosaceana* (Harris) and against the rose bud worm, *Olethreutes nimbatana*. The owner, sprayed a number of times at 7 to 10 day intervals with a standard pyrethrum spray, diluted 1 to 400. This spraying held the infestation in check but did not eliminate it. It appeared that a spray applied about every 10 days would be necessary to prevent the larvae from doing damage to the roses.

FUMIGATION WITH NICO-FUME PRESSURE FUMIGATORS.—Since the pyrethrum sprays were not giving very good control

and were costing more than the crop could afford, attention was given to other methods of control. The house was fumigated with *Nico-Fume Pressure Fumigators* with the idea that the nicotine vapors, if applied frequently enough, would kill the moths before they laid their eggs and, in time, the infestation could be cleaned up. Fumigations were made twice a week.

Each of the greenhouses fumigated has a capacity of slightly more than 525,000 cubic feet. Using the general recommendation of 1 pound *Nico-Fume*, containing 14 per cent actual nicotine, for each 25,000 cubic feet of space, it would require 21 pounds of *Nico-Fume* for each fumigation. Information obtained from the manufacturers indicated that by using the *Nico-Fume Pressure Fumigators* and applying the fumes directly to the plants, the amount of nicotine could be reduced.

**Table 1.—Fumigation with nico-fume pressure fumigators for control of *Platynota flavedena* Clem. on roses.**

| | House No. 1 | | House No. 2 | |
|---|---|---|---|---|
| Date | No. Cans | Applied | No. Cans | Applied |
| April 10 | 15 | In walk | | |
| 12 | 15 | In walk | | |
| 15 | 15 | In walk | | |
| 18 | 11 | Dry spray | | |
| 21 | 9 | Dry spray | | |
| 25 | 9 | Dry spray | | |
| 28 | 9 | Dry spray | 6 & 9 | Dry spray and in walks. |
| May 1 | 9 | Dry spray | 6 & 9 | Dry spray and in walks. |
| 5 | 9 | Dry spray | 6 & 9 | Dry spray and in walks. |
| 9 | 9 | Dry spray | 6 & 9 | Dry spray and in walks. |
| 12 | 9 | Dry spray | 6 & 9 | Dry spray and in walks. |
| 16 | 9 | Dry spray | 6 & 9 | Dry spray and in walks. |
| 19 | 9 | Dry spray | 9 | Dry spray |
| 23 | 9 | Dry spray | 9 | Dry spray |
| 28 | 9 | Dry spray | 9 | Dry spray |
| June 3 | 9 | Dry spray | 9 | Dry spray |
| 6 | 9 | Dry spray | 9 | Dry spray |
| 10 | | | 9 | Dry spray |
| 13 | 9 | Dry spray | 9 | Dry spray |
| 16 | | | 9 | Dry spray |
| 22 | 9 | Dry spray | 9 | Dry spray |
| 27 | 9 | Dry spray | 9 | Dry spray |
| July 3 | 9 | Dry spray | 9 | Dry spray |
| 7 | 9 | Dry spray | 9 | Dry spray |
| 11 | 9 | Dry spray | 9 | Dry spray |
| 14 | 9 | Dry spray | 9 | Dry spray |
| 18 | 9 | Dry spray | 9 | Dry spray |
| 21 | 9 | Dry spray | 9 | Dry spray |
| 25 | 9 | Dry spray | 9 | Dry spray |
| 28 | 9 | Dry spray | 9 | Dry spray |
| Aug. 1 | 9 | Dry spray | 9 | Dry spray |
| 4 | 9 | Dry spray | 9 | Dry spray |
| 8 | 9 | Dry spray | 9 | Dry spray |
| 12 | 9 | Dry spray | 9 | Dry spray |
| 17 | 9 | Dry spray | 9 | Dry spray |
| 22 | 9 | Dry spray | 9 | Dry spray |
| 27 | 9 | Dry spray | 9 | Dry spray |
| Sept. 1 | 9 | Dry spray | 9 | Dry spray |
| 8 | 9 | Dry spray | 9 | Dry spray |
| 15 | 9 | Dry spray | 9 | Dry spray |
| 22 | 9 | Dry spray | 9 | Dry spray |
| 29 | 9 | Dry spray | 9 | Dry spray |

METHOD OF FUMIGATING.—The first three fumigations were made by placing the one pound *Nico-Fume Pressure Fumigators* on the ground between the beds of roses. Both holes were punched out of fumigators and the cans were so placed that the smoke and fumes were directed lengthwise in the greenhouse. Fifteen one pound fumigators were used to a house.

The method of applying the nicotine was later changed. One hole only was punched out in the can. The cans were held by a special holder supplied for the purpose; after lighting the nicotine compound in the cans the operator walked backwards swinging the can from side to side and directing the smoke and nicotine fumes across the beds and just above the ground. There were 11 beds in each house. The fumigation was done from the walk between the 2nd and 3rd beds, the 5th and 6th, and the 9th and 10th beds. Three cans were used in each 600 foot walk, making nine one pound cans for the entire greenhouse. This gives one one pound per 4133 square feet, or one pound per approximately 25,000 cubic feet, figuring six feet as the height of fumigation.

In greenhouse No. 2, the plan of fumigation was different for the first six fumigations. In the west half of this house six one pound *Nico-Fume Pressure Fumigators* were used by directing the tobacco fumes across the benches and beneath the foliage on the roses. In the east half of the house, nine one pound cans were used by punching out both holes and placing the cans on the ground between the walks so that the fumes were directed lengthwise of the house. These two methods of fumigation were employed to determine whether there was any difference in the control to be obtained.

Since there did not seem to be any additional benefit derived from the additional *Nico-Fume* used in the above manner, the plan of fumigation was changed after the sixth fumigation to that employed in house No. 1.

TIME OF FUMIGATION.—The fumigation was done mostly at about 11 p.m. However, some of the fumigations were made about 8:30 to 9:00 p.m., just about dark. The ventilators were closed long enough before fumigation to permit the air to become quiet. Fumigation was done at about 11 p.m., because observations had indicated that air currents were less strong at this time and the tobacco smoke and fumes would hang close to the ground

for a longer time than they would earlier in the evening.

DATES OF FUMIGATION AND AMOUNTS USED.—The following table shows the dates of fumigation for houses Nos. 1 and 2, the number of one pound *Nico-Fume Pressure Fumigators* used, and the method of application. "In walks" indicates that the cans had both openings punched out, were set on the ground in the walks, and the nicotine compound was then lighted. The term "dry spray" indicates that the cans had one hole only punched out, were held by the special holders, the nicotine compound lighted, and the fumes directed across the benches and below the upper part of the rose foliage.

From April 10, when the first fumigation was started in house No. 1, to the end of September, 380 one-pound *Nico-Fume Pressure Fumigators* were used in house No. 1 and 360 one-pound cans in house No. 2. This is a total of 740 pounds used in controlling this leaf roller.

METHOD OF MAKING OBSERVATIONS.—At the beginning of the fumigation in house No. 1, all the rose tips infested with the leaf roller larvae were collected from 300 plants of each of the three following varieties: Better Times, Hollywood, and Autumn. Once each week collections were made from these same plants to obtain any new infestation showing up or any larvae missed during the preceding collection. In table 2 are shown the data from these collections.

After May 19, only an occasional young larva could be found. Observations on the remaining rose plants in house No. 1 showed very little new infestation and most of the old infested leaves to be without larvae.

At the time of starting the fumigation, house No. 1 had a heavier infestation than house No. 2. However, from April 10th, when the fumigation was started in house No. 1, to April 28th, when the fumigation was started in house No. 2, the infestation in house No. 2 had increased tremendously. A collection of all the infested rose tips in house No. 1, which had been fumigated six times since April 10th, from 800 plants where no collections had been made before, showed 69 larvae. A collection from 800 plants in house No. 2 where no fumigation had been done yielded 450 larvae. There were many small larvae among those collected in house No. 2, while those collected in house No. 1, included but few small larvae.

It will be noticed that after fumigating twice a week in house No. 1, up to June 6th, the owner fumigated next on the 13th and then on the 22nd of June. It seemed that since the infestation had been reduced so that almost no young larvae or new injury could be found, fumigating once a week would be sufficient. However, some new injury began to show up about the 22nd of June so fumigation twice a week was resumed. It is possible that some of this infestation may have been coming

**Table 2.—The number and size of larvae collected from rose plants fumigated with nico-fume pressure fumigators.**

| DATE | NO. OF TWIGS SHOWING INJURY AND SIZE OF LARVAE | | |
|---|---|---|---|
| | Variety—Better Times | Hollywood | Autumn |
| April 12 | 20 all sizes. | 16 all sizes. | 60 all sizes. |
| 18 | 18 2 pupae, others ½ to full grown. | 4 1 small, 2 large. | 16 ½ to full grown. |
| 25 | 24 15 less than ½ grown, 9 ½ grown or larger. | 43 36 less than ½ grown, 7 ½ grown or larger. | 22 15 less than ½ grown, 7 ½ grown or larger. |
| May 2 | 12 7 less than ½ grown, 8 more than ½ grown. | 48 26 about ½ grown, 22 more than ½ grown. | 13 5 less than ½ grown, 8 more than ½ grown. |
| 9 | 18 6 less than ½ grown, 12 more than ½ grown. | 21 6 less than ½ grown, 15 more than ½ grown. | 18 4 about ½ grown, 14 more than ½ grown. |
| 19 | 6 3 about half grown and 3 almost full grown. | 4 larvae all nearly full grown. | 5 1 pupa and 4 larvae almost grown. |

from outside the greenhouse, since the larvae are reported to be general feeders. Fumigation was continued twice a week up to the 1st of September when it was reduced to once a week. At the end of September only an occasional larva could be found.

SUMMARY AND CONCLUSIONS.—*Platynota flavedana* has not previously been reported as a pest of greenhouse roses. In greenhouses in Cranbury, N. J., it was doing considerable damage to foliage and buds until brought under control.

Information on the life history, habits and food plants of *Platynota flavedana* is very meager. Previous records have reported it merely as a general feeder. During the spring and summer months the life cycle appeared to require about five to six weeks.

Sprays containing the active principles of pyrethrum flowers, which have proven effective against other leaf rollers attacking greenhouse roses, were not practical against *Platynota flavedana*. The control was poor and the cost was high.

Fumigating twice a week at regular intervals with *Nico-Fume Pressure Fumigators* killed the adults before they laid many eggs. By directing the nicotine fumes across the beds and beneath the foliage of the rose plants, a greatly reduced dosage of nicotine could be used. Nine one pound *Nico-Fume Pressure Fumigators*, used in the above manner, twice a week, gave better control than a pyrethrum and soap spray, and at a greatly reduced cost.

Fumigation with the *Nico-Fume Pressure Fumigators*, where the nicotine fumes could be directed on the plants in an initial heavy concentration, permitted use of smaller amounts of material.—11-16-39.

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# Toxicity Studies of Mixtures of Nicotine and Naphthalene as Fumigants

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Both nicotine and naphthalene are important greenhouse fumigants. Nicotine is especially effective against aphids[2] and naphthalene against thrips and the common red spider (Whitcomb 1935), though undoubtedly each has a toxic effect on many other pests. The studies described herein were made to ascertain whether the two gases form a compatible mixture from an insecticidal standpoint and, if so, whether any increase in toxicity is obtained. Sub-lethal concentrations of naphthalene combined with lethal concentrations of nicotine were tested against the green peach aphid and sub-lethal concentrations of nicotine combined with lethal concentrations of naphthalene against the greenhouse whitefly.

LITERATURE.—Speyer (1933) stated that the addition of nicotine to powdered naphthalene gave promise of good results

[1] The writer acknowledges with thanks the laboratory assistance of A. H. Casanges and the help in preparation of the fumigation apparatus given by O. A. Nelson, both of the Bureau of Entomology and Plant Quarantine.

[2] Laboratory studies of nicotine as a fumigant against various insects, including aphids, thrips, and whiteflies. Richardson, H. H. In preparation.

against thrips. A dust containing 6 ounces of naphthalene and 0.3 ounce of nicotine when broadcast on the floor of a 1,500 cubic-foot greenhouse was effective against various greenhouse thrips. The question arises, however, whether naphthalene alone, which is very toxic to thrips, might not have been just as effective. Whitcomb (1935) reported that no injury resulted to carnation plants when a mixture of naphthalene and nicotine was vaporized in hot pans, but he makes no comment on insecticidal action. A mixture of tobacco dust with naphthalene flakes has been sold and used commercially as a greenhouse insecticide in the United States since 1930 (Whitcomb 1935). Apparently there has been little investigation of the toxicity of mixtures of gases of these two poisons for insect control.

INSECTS AND METHODS.—Green peach aphids (*Myzus persicae* Sulz.) grown on turnip and greenhouse whiteflies (*Trialeurodes vaporariorum* (Westw.)) grown on tomato and bean were used in the tests. A series of nine comparative tests indicated that the resistance of the whiteflies grown on the two host plants was about the same. All insects were fumigated in glass flasks without their host plants. Leaves infested with aphids were removed from the plants and the aphids allowed to leave naturally. These were then transferred by camels-hair brushes into test tubes, where they were kept for a short time before fumigation. The whiteflies were gathered by suction into a small test tube and then transferred to the fumigation flask by shaking. About 25 to 50 adult aphids and 100 or more adult whiteflies of mixed ages were used in each of the two fumigation flasks. The air-flow apparatus described by Richardson & Busbey (1937) was modified by attaching to the dilution line of the mixing flask a saturator tube filled with coarsely ground naphthalene, similar to the tube used by Lehman (1930). In the aphid tests the saturator tube was attached by a short piece of synthetic rubber tubing. Insecticidal tests have indicated that there is no loss in efficiency due to sorption by this tubing. In the whitefly tests, however, a ground-glass connection was sealed to the mixing bottle so that after the gas evolved it made contact only with glass until it passed the fumigation flasks. Passage of air through the saturator at the rate of about 6 liters per hour (temperature 25 degrees C.) gave a concentration of 0.56 milligram of naphthalene per liter (approximately 0.035 pound per 1,000 cubic feet), as calculated by loss of weight. This figure agrees closely with the concentration present at saturation at this temperature (Roark & Nelson 1929) and appears in line with Lehman's findings (1930) at 30 degrees C., though Lehman used nearly 10 times the air flow used here. Various concentrations of both naphthalene and nicotine were obtained by dilution of the gas-saturated air as previously described for nicotine (Richardson and Busbey 1937). Air flows were measured with flow-meters. The temperature of fumigation was kept at 25 $\pm$0.5 degrees C. Relative humidity was controlled by bubbling the air through bottles containing various concentrations of sulfuric acid to obtain approximately zero and 75 per cent relative humidity. These values were checked with a dew-point apparatus. Air flows of approximately 6 liters per hour were used in all tests and a preliminary sweep-out period of 3 hours or more was made before fumigation. For the recovery period fumigated insects were kept at 25 degrees C. and at 65 to 70 per cent relative humidity in small cages provided with their food plant. Mortality counts of aphids were made after 24 hours and of whiteflies after 24 or 48 hours. Tests had indicated that there was little change in mortality after 24 hours. Little mortality occurred with untreated check insects (0.8 per cent of 531 aphids and 5.5 per cent of 1,221 whiteflies). The mortality of untreated whiteflies was taken into account in calculating net mortality.

RESULTS.—A preliminary series of tests with the green peach aphid indicated that low concentrations of naphthalene (0.006 to 0.017 milligram per liter) increased the toxicity of nicotine (0.01 to 0.017 milligram per liter) very little. Another series of half-hour exposures at approximately zero per cent relative humidity was tried in which the nicotine concentration was kept constant at approximately 0.0084 milligram per liter and naphthalene concentrations were increased from 0.035 to 0.19 milligram per liter, the latter being approximately one-third of saturation. This nicotine concentration alone gave mortalities of 40, 35, 42, 43, 46, and 43 per cent, averaging 41 per cent, and was used

for the reason that any changes in efficiency would be more sensitively recorded in this region of mortality. (Figure 1.)

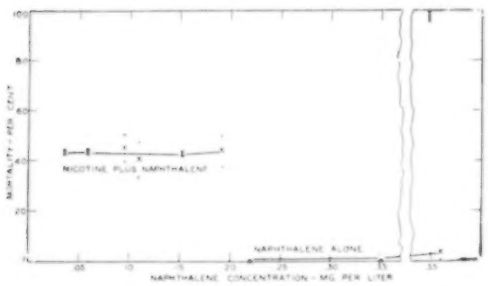


FIG. 1.—Toxicity to the green peach aphid of naphthalene and mixtures of naphthalene and nicotine. (Nicotine at 0.0084 mg. per liter.) (One-half-hour exposures at 25 degrees C.) Points represent individual tests and crosses averages.

Compared with the average kill of 41 per cent for nicotine alone, there appears to be little increase in efficiency against aphids from the addition of concentrations of naphthalene up to one-third of saturation. The two fumigants appear compatible, however. Naphthalene alone gave no kill at 0.21 and 0.34 milligram per liter and only 4 per cent in approximately saturated atmospheres (0.56 milligram per liter) in half-hour exposures, although in the highest concentration the aphids were entirely paralyzed before 10 minutes had elapsed.

In tests with the greenhouse whitefly mixtures of sub-lethal concentrations of nicotine with lethal concentrations of naphthalene were used. Previous work with nicotine indicated that under practical conditions 80 and 95 per cent of the toxic effect of nicotine fumigation takes place in the first 30 and 60 minutes, respectively, so that these exposures were not extended much over an hour. The results with nicotine alone, naphthalene alone, and mixtures of the two are shown in figure 2. The curves drawn in this figure were fitted by eye.

As can be seen, naphthalene alone (0.56 milligram per liter) is rather toxic to whiteflies. The addition of nicotine (0.004 to 0.006 milligram per liter), however, increases very definitely the speed of paralysis. For example, most whiteflies were paralyzed in approximately 25 to 30 minutes by either of the above concentrations of naphthalene or nicotine alone, but the mixture paralyzed them in $2\frac{1}{2}$ to 3 minutes. The mortality is also increased, especially so in the lower part of the mortality curve. In the mixture the higher concentration of nicotine (0.006 milligram per liter) seemed slightly more effective than the lower (0.004 milligram per liter) but the difference was not great. Relative humidity seemed to have little effect on the efficiency of the mixture, but if there was any difference it favored the low humidity. The sweep-out periods were made sufficiently long so that the difference in relative humidity would not affect the efficiency of nicotine (Richardson and Busbey 1937). If high moisture conditions are needed for efficient naphthalene fumigation, as recommended by Speyer (1925), Hartzell (1926, 1929), and Whitcomb (1935), it is strange that the mixture was not more effective at high humidity. These tests might indicate that relative humidity does not have a very great effect on the efficiency of naphthalene against whiteflies. The 75 per cent relative humidity used approximates the 75 to 80 per cent relative humidity recommended by the previously mentioned authors for naphthalene fumigation, but increasing toxicity may appear at higher relative humidities.

In another series of tests naphthalene (approximately saturated) was again com-

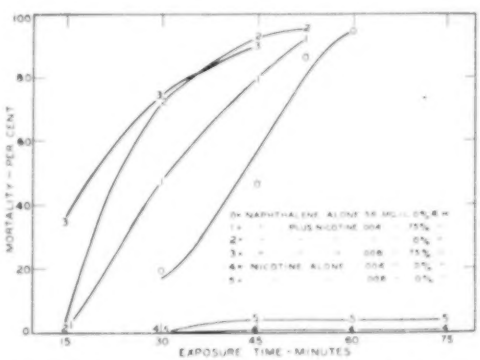


FIG. 2.—Toxicity to the greenhouse whitefly of nicotine and naphthalene and their mixtures at various exposure periods (25 degrees C.). Each point represents the average of two tests.

pared with mixtures of naphthalene and nicotine (0.006 milligram per liter) at exposure periods ranging from 45 to 75 minutes. The naphthalene fumigations were made in a separate apparatus with rubber-stoppered flasks similar to those used

by Lehman (1930) and were carried out at the same time as the naphthalene plus nicotine fumigations. The results are shown in table 1.

**Table 1.—Comparative efficiency of naphthalene alone (0.56 milligram per liter) and in combination with nicotine (0.006 milligram per liter) against the greenhouse whitefly. (Temperature 25 degrees C., relative humidity approximately 0 per cent.)**

| Exposure Period, Minutes | Per Cent Mortality Given by— | | Difference, Per Cent |
|---|---|---|---|
| | Naphthalene | Naphthalene Plus Nicotine | |
| 45 | 47.9 | 73.0 | 25.1 |
| 45 | 31.6 | 72.7 | 41.1 |
| 60 | 61.0 | 96.8 | 35.8 |
| 60 | 76.3 | 96.7 | 20.4 |
| 60 | 46.1 | 96.8 | 50.7 |
| 75 | 89.8 | 100.0 | 10.2 |
| 75 | 73.3 | 99.3 | 26.0 |
| 75 | 75.2 | 100.0 | 24.8 |
| Average | | | 29.26 ± 4.5 |

When the length of exposure ranged from 45 to 75 minutes, the average range in mortality for the eight series of comparative tests with approximately 2,000 whiteflies was 39.7 to 79.4 per cent for naphthalene alone and 72.8 to 99.8 per cent for naphthalene with nicotine. Higher mortality was given by the mixture in all eight tests, the average difference in mortality between pairs being 29.26 per cent, with a standard error of 4.5. The mixture was very definitely more effective. The insects in this second series appeared to be somewhat more resistant, but the differences between naphthalene alone and naphthalene with nicotine were similar to those found in the first series.

DISCUSSION.—Low humidity is preferable for nicotine fumigation, whereas high humidity is said to be essential for maximum efficiency of naphthalene (Whitcomb 1935), although these studies with mixtures do not confirm this latter point. Nicotine can apparently be used at high humidity without great loss of efficiency if excessive moisture is not present. The present study indicates, however, that the two gases are compatible at either high (75 per cent) or low (zero per cent) relative humidity, and that an apparently additive—possibly synergistic—effect takes place against whiteflies. In these studies no attempt has been made to test this latter point statistically.

SUMMARY AND CONCLUSIONS.—Laboratory tests were made on the fumigating action of nicotine and naphthalene and their mixtures on the green peach aphid (*Myzus persicae* Sulz.) and the greenhouse whitefly (*Trialeurodes vaporariorum* (Westw.)). All insects were fumigated off their host plants by an air-flow method, which tended to keep the gas concentration constant in the fumigation flasks during the entire exposure period.

When sub-lethal concentrations (0.006 to 0.19 milligram per liter) of naphthalene were added to a lethal concentration of nicotine (0.0084 milligram per liter), the fumigants appeared compatible, but no increase in toxicity over nicotine alone could be detected against the green peach aphid in half-hour exposures at 25 degrees C. Naphthalene alone in concentrations up to approximate saturation (0.56 milligram per liter) and at the same exposure had little efficiency.

Against the greenhouse whitefly the addition of sub-lethal concentrations of nicotine (0.004 to 0.006 milligram per liter) to lethal concentrations of naphthalene (approximately 0.56 milligram per liter) increased efficiency very definitely over naphthalene alone in exposures of 15 to 75 minutes (25 degrees C.). The speed with which the whiteflies were paralyzed by the mixture was also increased considerably over either naphthalene or nicotine alone. Low and high relative humidity (approximately zero and 75 per cent) appeared to have little effect on the efficiency of the mixture. The naphthalene-nicotine combination seems worth testing under practical conditions.—11-16-39.

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# The Grape Plume Moth[1]

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In eastern Massachusetts, especially in Metropolitan Boston, a majority of the home gardens contain one or more grapevines growing on arbors or trellises. In recent years nearly all of these vines have been attacked by the grape plume moth, *Oxyptilus periscelidactylus* (Fitch). Often the characteristically webbed leaves are abundant and very conspicuous. Typical counts made near Waltham in 1939 showed that 32 to 78 per cent of the buds were infested.

This condition has provoked a great many requests for control recommendations and, although it was carefully explained that the insect caused little actual damage to the fruit or vine and that pinching by hand was the usual method of killing the caterpillars, it was quite evident that the advice was neither satisfactory nor convincing.

HISTORY.—The grape plume moth, or the gartered plume moth, has been the subject of brief reports for about 50 years but none of these reports includes complete life history records. Lintner (1896) summarized the observations of Riley, Fernald, Saunders, and himself to conclude that there was one generation annually, contrary to the previous two generation idea, but he did not know whether the insect hibernated as the adult, which Riley suggested, or as the egg, which Saunders suggested. Apparently, observations on oviposition have not been made, since the life history records include no description of the egg nor any reports on oviposition.

The grape plume moth has not become an important pest in commercial vineyards and apparently the observations reported in 1896 have been generally accepted in more recent text books and bulletins which state that "the eggs have not been observed" (Slinglerland and Crosby, 1922), and "the simplest remedial treatment is to crush each larva by pinching its nest with the thumb and forefinger" (Britton, 1914).

NATURE OF INJURY.—Injury to grapevines by the grape plume moth is relatively insignificant and is caused entirely by the larva or caterpillar which feeds on the foliage and webs together the leaves of the terminal buds. The actual feeding on the foliage may result in small skeletonized areas eaten in the leaves of the swelling bud by the newly hatched larva, or in moderately large skeletonized areas eaten by the caterpillar in the webbed terminal leaves.

Occasionally the newly hatched larva feeding in the bud injures or destroys one or more of the embryo flowers and the growing larva may eat a blossom cluster which has been enclosed in its web. However, most of the blossom clusters grow far enough behind the terminal so that they are not attacked.

Since feeding is completed early in June while the grape canes are still making rapid growth, the injury is scarcely noticeable by midsummer. The absence of greater infestations in commercial vineyards is thought to be due partially to thorough pruning which annually removes many of the canes on which eggs have been laid and partially to the thorough application of a spray schedule to combat other pests.

SEASONAL HISTORY AND DESCRIPTION.—Contrary to several published records, the grape plume moth spends the winter in the egg stage and has but one generation annually in Massachusetts.

*The eggs* are laid singly but are frequently deposited in groups of two to ten. They are usually placed in the small

[1] Contribution 356 of the Massachusetts Agricultural Experiment Station.

crotch between branches on old canes (Fig. 1). In this location, they are imbedded in the pubescence on the cane and may not be visible to the naked eye, although a small part of the egg is usually exposed. An examination of 106 inches of cane cut at random from infested vines revealed 22 eggs at seven nodes. None has been found on the current season's growth.

The average egg is .56 mm long and .39 mm wide, broadly elliptical in general shape but slightly narrower at one end. It is well rounded at the sides and ends but in the center of the upper and lower surfaces there is a small flattened area (Fig. 1). When first laid, the egg glistens and is light yellowish-green in color but it soon changes to a light iridescent brown. Incubation is apparently completed in three to four weeks, but the larva remains inactive in the eggshell until the following spring.

*The larva* hatches at the time the buds are swelling. In 1939, the hatching period was May 7–10. It soon enters the swelling bud and for about 10 days is difficult to find. When the grape shoot begins to lengthen and the leaves unfold, the caterpillar fastens together the edges of one or more leaves and feeds within the shelter thus formed. Usually this shelter is near the tip of the shoot and frequently it encloses the entire tip. The feeding period continues for about 30 days and in 1939 was completed about June 10.

When first hatched, the larva is shiny and pale yellowish-green in color. After the first molt, it is abundantly covered with long, pale yellow hairs and has a fuzzy appearance. When full grown it is 13 to 16 mm. long.

*The pupa* is 8 to 10 mm. long, naked, and light green or brown in color. It is conspicuously marked with two parallel appendages protruding dorsally from the first abdominal segment. These "fins" are shaped somewhat like a spear point and are dark brown in color. Smith (1909) refers to them as the "breast bone" but since they are located on the back this term is somewhat misleading.

Pupation took place from June 10 to 15 in 1939. When ready to pupate, the mature larva suspends itself posteriorly, usually within the webbed leaf, where it spends a pupal period averaging 11.6 days.

*The adult* emerges during late June and early July. The moth is not a strong flier and is most active at night. When at rest it frequently hangs by the front and middle legs with the body and hind legs perpendicular to the surface from which it depends. In the insectary the average life of the male moths was 7.5 days and

FIG. 1.—Grape Plume Moth. Left, Eggs in typical location on grape cane. Right, eggs, enlarged ten times.

that of the females was 11.5 days. In captivity only one-third of the mated females laid eggs and all oviposition occurred from June 30 to July 4. The maximum number of eggs laid by a single moth was 21 and the average number was 12.6.

The moth is typical of the family *Pterophoridae* the forewings being partially divided into two parts and the hindwings completely divided into three parts, with a wing spread of 15 to 18 mm. It is light brown in color with numerous dark brown spots on the wings, abdomen, and legs. The legs are conspicuously long and slender, with two pairs of long tibial spurs on the hind legs and one pair on the middle legs.

CONTROL BY DORMANT SPRAYING.—Experimental spraying both in the laboratory and in small home vineyards killed the overwintering eggs of the grape plume moth.

In the laboratory 90 per cent of the eggs on infested grape canes were killed by an application of oil emulsion, sodium dinitro cresylate or lime-sulfur concentrate.

In the home vineyards the sprays were applied with a wheelbarrow type sprayer at about 125 pounds pressure. The application was made April 21 when the buds were starting to swell and about two

weeks before the first larvae hatched. In Experiment 1, the vines were growing on individual trellises and each trellis received a separate treatment. In Experiment 2, the sprays were applied to different sections of a large arbor. All of the vines were at least twenty-five years old and had received the usual amateur pruning and training. Most of the vines were Concord, Delaware and Niagara, and none of the sprays caused noticeable injury to the vines of these varieties.

**Table 1.—Control of grape plume moth.**

| Insecticide | No. of Buds Examined | No. of Vines Examined | Per Cent Buds Infested |
|---|---|---|---|
| **Experiment 1, Waltham, Massachusetts** | | | |
| Liquid lime sulfur concentrate—1% | 247 | 2 | 63.15 |
| Oil emulsion 3% actual oil[2] | 100 | 1 | 5.00 |
| Sodium dinitro cresylate—1%[3] | 295 | 3 | 2.37 |
| None | 362 | 4 | 55.52* |
| **Experiment 2, West Newton, Massachusetts** | | | |
| Liquid lime sulfur concentrate—1% | 118 | 1 | 62.71 |
| Oil emulsion—3% actual oil[2] plus 40% nicotine sulfate—0.125% | 100 | 1 | 19.00 |
| Sodium dinitro cresylate—1½%[3] | 100 | 1 | 7.00 |
| None | 300 | 2 | 77.67 |

* Infestation varied from 69 to 32 per cent on different vines.

The vines were examined when the plume moth larvae were about two-thirds grown and the webbed buds were very conspicuous. The results were classified according to the number of infested terminal shoots.

The best control was obtained with a sodium dinitro cresylate composition[2] diluted to 1 per cent and 1½ per cent. Although used in a different experiment, the 1½ per cent dilution was not more effective than the 1 per cent dilution. A commercial oil emulsion[3] diluted to contain 3 per cent actual oil also gave good control, and its effectiveness was not increased by the addition of 40 per cent nicotine sulfate at the rate of 1 part in 800 parts of the spray. Lime-sulfur concentrate (33° Bé) diluted with 8 parts of water failed to give control even though it had appeared very promising in earlier experiments in the laboratory.

SUMMARY.—The grape plume moth has one generation annually in Massachusetts. The eggs, which have not previously been described, are laid singly in late May and early June. They are imbedded in the pubescence at the axil of a branch or bud on the older grape canes. In experiments, a dormant application of either 1 per cent sodium dinitro cresylate or oil emulsion diluted to contain 3 per cent actual oil gave satisfactory control without injury to the vines.—11-16-39.

[2] *Elgetol* manufactured by Standard Agricultural Chemicals, Inc.
[3] *Kleenup* manufactured by California Spray Chemical Co.

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# Some Scientific Contributions Made at the Port of New York

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World news on epidemic outbreaks of injurious insects or plant diseases rarely appears in print in time to warn importing countries. It is, of course, impractical for the United States to keep scientists surveying the fields, forests, and orchards for pest conditions in all parts of the world, and while information gathered in that manner would be useful for plant quarantine purposes, it probably would not present a true picture as applied to this country, since many of the most injurious introduced pests are of little economic importance in their native land. Compare the slight damage done by the Japanese beetle in Japan with the extensive injury in the United States (Clausen *et al.*, 1927). The white-fringed beetles, *Pantomorus*

spp., particularly *P. leucoloma* (Boh.) are only occasionally recognized as injurious insects in South America (Berry, 1939).

Foreign products are actually brought to the very door of the plant quarantine inspector to determine what pest risks may be involved. Inspections have resulted in additions to the much needed data on world distribution of insect pests and plant diseases as well as the recording of new hosts for some of the economic forms. Facts are revealed as to the stage in which certain insects are found in certain products at certain seasons in certain parts of the world. Some findings have shown the relationship of a definite insect pest to an entire botanical group of plants growing in a certain portion of the globe. Indeed, if it were possible to record more detailed facts, each of the many important interceptions of plant pests listed annually by this Bureau would show behind it some interesting observation which would be a still greater contribution to science.

More writers on systematic and economic entomology and plant pathology should refer to the vast store of data available in those lists. With the splendid cooperation of the various specialists in the Division of Insect Identification of this Bureau and the Bureau of Plant Industry nearly all the data accumulated, including that given here, have been accurately recorded. Time allows me to cite only a few of the many scientific contributions.

CONTRIBUTIONS FROM FRUITS AND VEGETABLES.—An outstanding example of a scientific contribution made by the inspection force at New York is the finding of live larvae of the Mediterranean fruitfly (*Ceratitis capitata* (Wied.)) in grapes from Spain. Before this interception was made there was nothing in literature that would have led us to suspect its presence in this fruit. In fact many leading entomologists in the United States had not given grapes a thought as one of the many hosts of this pest. Since that finding many changes have been made in the regulations covering the importation of this product, and its status in international trade has been greatly affected.

The discovery at New York of Mediterranean fruitfly larvae in grapes grown in a South American country indicated that there were some areas in that country where this insect had become established.

Repeated findings of the Mediterranean fruitfly in known hosts from countries known to be infested are constantly being made at New York. This insect, positively identified, has been taken at New York in 25 hosts from Algeria, Argentina, Azores, Bermuda, Brazil, Cyprus, France, Germany, Greece, Italy, Malta, Madeira Islands, Palestine, Portugal, Sicily, Spain, and the Union of South Africa. Such findings in new hosts for certain countries are steadily increasing, while new countries of origin are less frequently listed.

Previously unrecorded hosts, recently found at New York infested by living larvae of the Mediterranean fruitfly include the fruit of a hawthorn (*Crataegus* sp.) from Italy and the spice berry (*Pimenta officinalis*) from Bermuda.

There are three references in foreign literature to the fresh date as a host of this fly. Only recently this fact was verified at the port of New York after a handful of such dates from Bermuda had been carefully examined. Figs grown in southern France were found similarly infested.

A brief review of the forms of *Anastrepha* spp. taken at New York shows 21 hosts from Argentina, Bahamas, Bermuda, Brazil, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, Guatemala, Haiti, Honduras, Jamaica, Mexico, Panama, Peru, Trinidad, Venezuela, Virgin Islands, Canal Zone, and Puerto Rico.

Some years ago, when inspectors at the port of New York repeatedly found live larvae of *Ceutorhynchus* sp., *Lixus* sp., *Baris* sp., *Psylliodes chrysocephala* (L.), and other insect pests in turnips, radishes, and rutabagas from various countries in Europe, the entry of these products from Europe was refused. Since that time certain botanically related products have been found similarly infested. The records show *Ceutorhynchus* sp. in cabbage leaves and leaf stems from eight European countries (Denmark, England, France, Germany, Holland, Italy, Poland, and Scotland), in cauliflower leaves and stems from six European countries (Belgium, England, France, Germany, Italy, and Scotland), and in stems of broccoli, kale, and turnip from Italy; and the chrysomelid *Psylliodes chrysocephala* (L.) in cabbage leaf stems from Denmark and Germany, in cauliflower leaf stems from

France, Italy, and Scotland, and in broccoli from Italy. Another slightly related product, horseradish (*Radicula armoracia*), from Czechoslovakia, Germany, Hungary, Italy, Poland, and Russia, was recently found at New York infested with live weevil larvae some of which, were identified as *Baris lepidii* Germ. and others as *Ceutorhynchus* sp., *Lixus* sp., *Cleonus* sp., etc. This product was accordingly taken off the list of vegetables approved for entry from the countries named. Irish sea kale (*Crambe maritima*) was also recently found at the port of New York infested with living larvae of *Ceutorhynchus* sp. and was taken off the permitted list. For the past several years Chinese cabbage (*Brassica chinensis*) grown in Cuba has been found at the port of New York infested with live larvae of *Ceutorhynchus* sp. Shipments of this product found so infested were refused entry.

The citrus blackfly (*Aleurocanthus woglumi* Ashby) was intercepted at the port of New York from Haiti on leaves of avocados at about the same time, or slightly before, the entomologists in that country realized that this pest had reached their groves. A later finding of the insect at New York among limes and lime leaves from Cuba verified the opinion that there were some isolated spots on that island, as well as some other West Indian islands, where the parasite introduced to control the blackfly had not thriven and the pest pest has continued its ravages locally.

From Italy and Algeria cardoon thistle (*Cynara cardunculus*), related to globe artichoke (*C. scolymus*), was found at the port of New York tunnelled by the larvae of *Apion* sp., which also attacks its relatives. Both of these products have now been removed from the permitted list.

When the inspection records of several years were studied, it was found that the bulbs of cipollini (*Muscari comosum*), known in the trade as "wild onion," from French and Spanish Morocco and, to a lesser extent, from Italy, when imported from the fall, winter, and early spring harvests were invariably infested with nearly full-grown larvae of *Exosoma lusitanica* (L.), a chrysomelid concerning which very little appears in literature. The adults are known, however, as general feeders, sometimes defoliating grapevines and other cultivated plants. Nothing seems to be known about egg deposition and very little about where the early stages of the larvae are passed. The larvae feed in cipollini bulbs, at least in the fall and winter, and creep out in the spring to complete their metamorphosis in the soil. When cipollini arrives at the port of New York in the spring it is noticed that many larvae crawl out over the cases and scatter in all directions. This observation gives us facts as to the seasonal history of the larvae in this host. On account of the treatment required when such infested importations arrive here, the Moroccan shippers are harvesting and storing as much as possible during the late spring and summer months in order to export bulbs from which *Exosoma* larvae have migrated (Hawkins, 1939).

The nut fruit tortrix (*Laspeyresia splendana* (Hbn.)) and its varieties have been intercepted in chestnuts from Austria, Azores, France, Germany, Greece, Italy, Portugal, Spain, Switzerland, and Yugoslavia. The chestnut weevils (*Balaninus* sp. or *Curculio* sp.) were taken here in this host from nine foreign countries (Austria, Azores, Greece, Italy, Japan, Portugal, Russia, Spain, and Yugoslavia). The largest shippers are Italy and Portugal. Not many years ago chestnuts from these countries arrived at our docks literally alive with the pests. A hot-water treatment for infested chestnuts was required. This treatment was considered expensive for the importers and in a short time our method of treatment was adopted by the governments of Italy and Portugal and was made more or less compulsory by those countries for all shipments destined to the United States. We now seldom find live specimens of either of these pests in commercial shipments from those two countries.

FRUITS AND VEGETABLES.—Some of the injurious insects intercepted in or on fruits and vegetables for the first time in new hosts or from new countries or both at the port of New York are the following:

*Phlyctinus callosus* Boh. among grapes from South Africa.

*Stenoma anonella* (Sepp.) in soursop from Costa Rica. Previously in custard apple from Barbados.

*Maruca testulalis* (Geyer) (bean pod borer) in string beans from Brazil. Previously in this host from Cuba and Puerto Rico, in lima beans from Cuba, and in

pigeon peas from Puerto Rico. Not known to occur on the mainland of the United States.

*Aspidiotus perniciosus* Comst. on apples from Hungary. Appears to be the second record from Europe, a previous one having been from Yugoslavia. We have also intercepted this scale from Australia, Chile, New Zealand, Japan, Argentina, and Uruguay. It has been the cause of a considerable number of quarantine enactments by many foreign countries against American fruits.

The tingid *Stephanitis pyri* (F.) on persimmons from Italy.

The pentatomid *Edessa meditabunda* (F.) on grapes from Argentina.

*Lygaeus albo-ornatus* Blanch. on excelsior packing for grapes from Chile.

The pink bollworm (*Pectinophora gossypiella* (Saund.)) in green okra from the American Virgin Islands. A similar observation was made by Cooley on the Island of St. John, A. V. I., during the fruitfly survey of 1930–31 (Kisliuk & Cooley, 1933).

COTTON AND RELATED PLANTS.—A cotton stainer, *Dysdercus peruvianus* (Guerin), was taken at New York on seed cotton from Ecuador.

The pink bollworm was taken among seeds of *Abelmoschus manihot* from Brazil, and in cotton seeds from Uganda, East Africa. Previous records for New York show this pest as having been taken in cotton seed from Barbados, Brazil, China, Cuba, Dominican Republic, Egypt, Haiti, Italy, Jamaica, Malta, Montserrat, St. Lucia, Turkey, Puerto Rico, and the Virgin Islands.

NURSERY STOCK, PLANTS AND SEEDS.—*Chionaspis pinifoliae* (Fitch) is an insect of economic importance in the forests of the United States. It was intercepted on the needles of white pine from Germany, the first record from a European country.

*Stenoma catenifer* Wlsm. was taken in avocado seed from the Canal Zone.

The scarabaeid *Diaplochelus longipes* (F.) and the buprestid, *Sphenoptera* sp., were found in bud of *Protea* sp. from South Africa. Seventeen different insects are recorded at New York from this host from South Africa. It is considered that about half of these are injurious.

The alfalfa weevil (*Hypera postica* (Gyll.)) was intercepted on shamrocks from Ireland and on alfalfa from Germany.

The rose stem sawfly (*Allantus cinctus* (L.)) was intercepted in rose stems from Italy. Inspectors at New York have made previous interceptions of this insect from England, France, and Holland.

Larvae of the Japanese beetle and an Oriental garden beetle were intercepted in the soil about roots of plants from Japan.

*Hypoborus ficus* Erichs., a scolytid beetle, was found boring into a fig cutting from Italy.

The holly leaf miner (*Phytomyza ilicis* Curt.) was intercepted from France.

The bruchid *Specularius erythrinae* Brid. was taken in the poisonous seeds of *Erythrina* from South Africa.

In seeds of *Lathyrus* there were found weevils, *Apion pomonae* (F.), from Italy, and bruchids, *Bruchus tristiculus* Fahr., from the Azores and Holland, *B. tristis* Boh., from Italy, and *B. affinis* Froh. from Germany.

In clover seeds from England *Apion varipes* Germ. was intercepted.

In seeds of kudzu from Holland and Japan *Callosobruchus ademptus* (Shp.) was found.

PACKING MATERIALS.—*Chilo simplex* (Butter) was intercepted alive in rice straw from Spain. This was the first European record for New York. Previous interceptions have been from China, Egypt, India, Japan, Syria and Trinidad.

While straws were being examined it was discovered that straw jackets used to protect bottled merchandise were contaminated with portions of vetch plants, the unopened attached seed pods of which were infested with live bruchids throughout the year. (Roark, 1939.)

VETCH SEED.—The interceptions at New York have added data and verified facts already published. (Pierce, 1917.) Following are some distribution records from interceptions in *Vicia* seed:

*Bruchus brachialis* Fahr. Czechoslovakia, Germany, Holland, Hungary, Italy, and Switzerland.

*Bruchus dentipes* (Baudi) from Syria.

*Bruchus tristiculus* Fahr. from Azores, Holland, and Italy.

*Bruchus rufimanus* Boh. from Albania, Algeria, Azores, Czechoslovakia, England, France, Germany, Greece, Holland, Hungary, Ireland, Italy, Morocco, Palestine, Poland, Rumania, Tunis, and Yugoslavia.

*Bruchus laticollis* Boh. from Italy.

*Bruchus rufipes* Hbst. from Czechoslovakia, England, France, Germany, Holland, Hungary, Italy, Jamaica, Poland, Portugal, Rumania, Scotland, and Switzerland.

*Bruchus viciae* Oliv. from Italy.

*Bruchidius quinqueguttatus* (Oliv.) from Algeria.

*Bruchus luteicornis* Ill. from Cuba,[1] England, France, Italy, and Scotland.

*Callosobruchus analis* (F.) from British India.

In addition to, and sometimes associated with, these bruchids were weevils of *Apion craccae* L. from England, Germany, and Poland, and *Apion pomonae* F. from France, Germany, Holland, Ireland, Italy, Poland, Portugal, and Scotland.

Various hymenopterous parasites of the bruchids and the weevils were taken both dead and alive in the vetch seeds.

In an effort to avoid the treatment of straw jackets most of these which arrive as covers on bottles have lately been found to have been pressed flat or rolled before use so that the vetch seeds and the bruchids are crushed and broken up beyond recognition.

SUGARCANE AND BROOMCORN.—*Sesamia cretica* Led. was taken in sugarcane from the Madeira Islands, and, earlier in broomcorn from Italy and Morocco. *Pyrausta nubilalis* (Hbn.), was taken in broomcorn from Czechoslovakia, and earlier, in various products, from Italy, Hungary, Spain, and Yugoslavia.

MISCELLANEOUS INSECT CONTRIBUTIONS.—*Aedes aegypti* (L.) has been taken twice in seaplanes from Bermuda.

*Taeniothrips frici* (Uzel) was taken on squill bulbs from Italy.

In lentils imported for food there were intercepted *Bruchus lentis* Froelich from Belgium, Cyprus, Italy, and Egypt, and *Bruchidius incarnatus* (Boh.) from Egypt.

*Lyctus caribeanus* Lesne was taken in roots of *Smilax* from Puerto Rico.

Dried licorice roots from Turkey were found infested with *Bostrichus capucinus* (L.) and *Trogoxylon impressum* (Com.).

*Dinoderus biforeolatus* Woll. was taken in barbasco roots from Brazil and Peru and also in derris root from the Philippines. (Roark, 1939.)

FROM LOGS AND WOOD PRODUCTS.—Since the Dutch elm disease is distributed by boring insects interest in such insects has increased and many interceptions of such material are being added to the records.

*Ips typographus* (L.), considered by some economic entomologists as the most injurious bark beetle in Europe, was intercepted from Germany in pine boards used as crating. (Pierce, 1917.)

*Hylurgops palliatus* (Gyll.), an injurious insect in pine, was taken in that host from Czechoslovakia and Holland.

The cerambycid *Pogonocherus fasciculatus* (Deg.) was intercepted in pine from Sweden.

*Anthaxia quadripunctata* (L.) was taken in pine from Germany and Sweden.

*Pityogenes bidentatus* (Hbst.) was taken in pine slats from Holland.

*Hylobius abietis* (L.) was taken in pine from Sweden.

*Dinoderus minutus* (F.) was intercepted in logs, crates, and bamboo poles from China, Cuba, Dutch East Indies, Ecuador, France, Haiti, India, Japan, New Guinea, Peru, and Trinidad. This insect was also taken in roots, fruits, seeds, packing materials, grass stalks, etc., from Brazil, Colombia, Costa Rica, Cuba, Ecuador, Haiti, India, Jamaica, Morocco, Peru, Philippines, Scotland, and Trinidad. It is said to have been found recently in Florida.

There is a growing demand in many industries for tropical woods. Importations of tropical logs are being examined whenever time permits. Consequently many records of injurious insects are being added to the list. Among such records are the following six species of *Platypus: P. australia* Chapuis, from Australia; *P. emarginatus* Chapuis, from Guatemala; *P. excisus* Chapuis, from Mexico; *P. compositus* Say from Mexico; *P. omnivorous* Lea, from Australia; *P. rugulosus* Chapuis, from Cuba, Dominican Republic, Guatemala, Honduras, Mexico, Panama, and Salvador, in banana debris from Honduras, and in barbasco roots from Brazil.

*Stephanoderes braziliensis* Hopk. from Brazil and Cuba.

*Xyleborus affinis* Eichh. has been found in logs from Brazil, Dominican Republic, Ecuador, Guatemala, Mexico, Trinidad, and West Africa, in banana debris from Panama, and in tree seeds from Trinidad. *X. confusus* Eichh. in logs from Ecua-

[1] Records from Cuba and Jamaica probably involve reshipment of seeds from other foreign countries rather than shipments of seeds orginating in the countries concerned.

dor, Guatemala, Honduras, and Mexico, and in fruits, roots, etc., from British Guiana, Costa Rica, Cuba, Dominican Republic, Honduras, Jamaica, and Panama; *X. fuscatus* Eichh. in logs from Guatemala and Mexico; *X. hubbardi* Hopk. in logs and on line fruit from the Dominican Republic; *X. kraatzi* Eichh. in a log from Australia; *X. monographus* (F.) in a log from Belgium; *X. propinquus* Eichh. in tropical logs from Guatemala, Mexico, and Panama, in the fruit of mango from Brazil, Canal Zone, and the Dominican Republic, and in banana debris from Panama; *X. sacchari* Hopk. on a log from Cuba.

The insect examples cited here are but a few of the scientific contributions made in the course of the inspection work at the port of New York.—11-17-39.

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Annual Letter of Information No. **40.**
Annual Letter of Information No. **41.**
List of Pests Intercepted on Imported Plants and Plant Products December 1930, March 1932, December 1932, December 1933, July 1935, August 1936, June 1937 and May 1939.


# Insecticide Tests Against the Pecan Nut Casebearer in Texas in 1938


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Spraying experiments for the control of the first generation of the pecan nut casebearer (*Acrobasis caryae* Grote) were conducted in southern Texas in 1938. The purpose of the experiments was to determine the effectiveness of single applications of seven spray combinations, four of which had apparently not been previously used against this insect.

EXPERIMENTAL PROCEDURE.—These studies were conducted in two orchards, both of which were heavily infested with the casebearer. Orchard 1 consisted of 14-year-old trees and experiments, mostly duplicating each other, were carried on in two different sections of the planting. Orchard 2 consisted of 10-year-old trees. The trees in each orchard were planted equal distances. Several of the treatments were replicated. Usually ten or more trees were used in a treatment and never fewer than four trees. A single application was made of each material. In regard to thoroughness and speed, the spraying was similar to that in good commercial practice. All the work was done with a power machine at a pressure of 500 to 600 pounds. A single-head spray gun with disk aperture was used on the upper portions of the trees and a four nozzlehead gun on the lower branches. All spraying was done from the ground and each tree

[1] L. L. Bolt and J. P. Hipp assisted in recording the nut-cluster infestation counts given in this paper.

was sprayed in one operation until the foliage began to drip.

Information on the effect of the nut casebearer infestation on sprayed and on check trees was obtained by infestation counts, by counts of nuts in tagged clusters, by weight of nuts harvested, and by counts of hibernacula.

The infestation counts were made at the end of the feeding period of the first-generation larvae and representative samples of about 300 to 800 nuts from each tree were examined.

**Table 1.—Effect of the various sprays on several varieties of pecan trees, Crystal City, Tex., May 1938.**

| Spray Treatment | Number of Trees | Percentage of Nuts Infested | Percentage Reduction in Infestation |
|---|---|---|---|
| *Burkett* Orchard 1, section A | | | |
| Lead arsenate* | 10 | 46.5±1.9 | 46.4±2.3 |
| Lead arsenate | 5 | 19.6±2.8 | 77.4±3.2 |
| Lead arsenate-Summer oil | 10 | 12.5±1.3 | 85.6±1.5 |
| Lead arsenate-Soybean flour | 11 | 24.5±1.8 | 71.7±2.1 |
| Cryolite | 6 | 34.6±1.6 | 60.1±1.9 |
| Check | 11 | 86.7±1.0 | — |
| *Burkett* Orchard 1, section B | | | |
| Lead arsenate | 10 | 32.2±1.5 | 56.2±2.8 |
| Lead arsenate-Summer oil | 10 | 24.6±1.8 | 66.6±2.9 |
| Lead arsenate-Soybean flour | 10 | 12.7±1.3 | 76.3±3.5 |
| Cryolite-Summer oil | 5 | 15.5±1.9 | 79.0±2.8 |
| Check | 10 | 73.6±3.4 | — |
| *Burkett* Orchard 2 | | | |
| Lead arsenate | 7 | 15.1±1.0 | 81.3±1.3 |
| Lead arsenate-Summer oil | 10 | 19.8±1.6 | 75.5±2.0 |
| Lead arsenate-Soybean flour | 10 | 21.6±1.4 | 73.2±1.8 |
| Check | 12 | 80.7±1.5 | — |
| *Halbert* | | | |
| Lead arsenate | 6 | 15.2±1.5 | 75.4±2.8 |
| Lead arsenate-Summer oil | 4 | 9.7±1.7 | 84.4±2.9 |
| Check | 8 | 61.8±3.8 | — |
| *Humble* | | | |
| Lead arsenate-Summer oil | 8 | 10.7±2.1 | 86.9±2.6 |
| Check | 6 | 81.3±3.5 | — |
| *Texas Prolific* | | | |
| Lead arsenate-Summer oil | 10 | 9.1±0.6 | 83.7±1.3 |
| Lead arsenate-Sulfated alcohol | 8 | 7.0±0.9 | 87.5±1.7 |
| Check | 11 | 55.9±2.8 | — |
| *Western Schley* | | | |
| Lead arsenate-Sulfated alcohol | 5 | 13.5±1.5 | 72.7±5.0 |
| Check | 4 | 49.4±7.0 | — |

* Four pounds per 100 gallons; in all other treatments 6 pounds per 100 gallons.

Counts of nuts in clusters were made at intervals beginning in April and continuing until the nuts matured in October. Serially numbered tags were placed on 100 nut clusters on each of 15 trees, 5 trees for each treatment. Fifteen similar trees were used as checks.

MATERIALS AND MIXTURES.—The stomach poisons tested were commercial acid lead arsenate and natural cryolite (sodium fluoaluminate). A commercial summer oil emulsion (approximately 80 per cent oil), soybean flour, and sulfated alcohol were added to some sprays. Zinc sulfate was added to all sprays, primarily to control pecan rosette, but it also reduced the danger of arsenical burning. The spray combinations and quantities of materials per 100 gallons were as follows:

Lead arsenate 4 pounds.

Lead arsenate 6 pounds.

Lead arsenate 6 pounds plus summer oil emulsion 1 gallon.

Lead arsenate 6 pounds plus soybean flour 1 pound.

Lead arsenate 6 pounds plus sulfated alcohol 1 fluid ounce.

Cryolite 6 pounds.

Cryolite 6 pounds plus summer oil emulsion 1 gallon.

Zinc sulfate 2 pounds.

INFESTATION RECORDS.—The effect of the different treatments on nut casebearer infestation is given in table 1. On the check trees of the Burkett and Humble varieties the casebearer destroyed more than 80 per cent of the nuts and on check trees of the Western Schley variety approximately 50 per cent.

**Table 2.—Nut production per cluster on pecan trees after different spray treatments, Crystal City, Tex., 1938.**

| Spray Treatment | Average Nuts per Cluster | | | |
|---|---|---|---|---|
| | Apr. 20–28 | May 19–25 | July 19–21 | Oct. 14* |
| *Burkett* | | | | |
| Lead arsenate-† Soybean flour | 3.7 | 2.0 | 1.3 | — |
| Check | 3.6 | .4 | .2 | — |
| *Halbert* | | | | |
| Lead arsenate | 4.3 | 3.2 | 2.0 | — |
| Check | 4.3 | 1.6 | .6 | — |
| *Humble* | | | | |
| Lead arsenate-Summer oil | 4.8 | 4.0 | 2.8 | 2.5 |
| Check | 4.5 | .5 | .3 | .2 |

* Nuts from trees of Burkett and Halbert varieties harvested early in October.

† Six pounds per 100 gallons in each treatment.

YIELD OF NUTS.—Table 3 presents records of the yield of pecan nuts from the different trees. Error determinations indicate that yield records were dependable when expressed on the basis of cross-sectional area or volume of tree top but were less accurate when expressed on a per tree basis.

All the spray combinations gave large increases in yield, varying with the treatment and the method of computing the

results. As a rule slightly larger increases in nut production resulted from the application of lead arsenate 6 pounds to 100 gallons with summer oil than with the same without oil. Neither soybean flour nor sulfated alcohol seemed to add to the effectiveness of lead arsenate. Trees in orchard 1 sprayed with lead arsenate at 4 pounds per 100 gallons and with cryolite without oil produced less than half the yield of those sprayed with lead arsenate at the 6 pound strength.

RECORDS OF HIBERNACULA.—On November 12 and 13 records were made of the number of hibernacula on 411 shoots from five Burkett trees that had received, on April 25, an application of lead arsenate 6 pounds to 100 gallons with summer oil, and 495 shoots from five Burkett check trees. Hibernacula were found on 11 per cent of the shoots of the sprayed trees and on 35 per cent of the shoots on the check trees; in other words, they were three times as abundant on the unsprayed trees. A little migration of second and third generation nut casebearers from check trees to treated trees probably occurred between May and November.

SUMMARY.—Experiments with spray materials for the control of the pecan nut casebearer were carried on at Crystal City, Tex., during 1938. The materials used included lead arsenate, alone and in combination with a summer oil emulsion, and with soybean flour and a sulfated alcohol, and cryolite with and without a summer oil. Single applications were used. The effectiveness of the various spray combinations was determined by infestation counts, counts of nuts on tagged clusters, weight of nuts harvested, and counts of hibernacula.

**Table 3.—Yield from pecan trees receiving various spray treatments, Crystal City, Tex., 1938.**

| SPRAY TREATMENT | NUMBER OF TREES | AVERAGE YIELD OF NUTS IN POUNDS | | |
|---|---|---|---|---|
| | | Per Tree | Per 1 Square Foot Cross Section of Trunk | Per 1,000 Cubic-Foot Volume of Tree Top |
| *Burkett* | | | | |
| Orchard 1, section A | | | | |
| Lead arsenate* | 14 | 9.8±1.0 | 15.9±1.6 | 0.8±0.1 |
| Lead arsenate | 9 | 21.3±1.8 | 40.3±3.4 | 2.8±0.3 |
| Lead arsenate-Summer oil | 12 | 16.5±1.5 | 41.3±2.7 | 3.1±0.2 |
| Lead arsenate-Soybean flour | 15 | 13.9±1.3 | 26.2±2.4 | 1.6±0.1 |
| Cryolite | 7 | 7.8±0.5 | 13.4±0.9 | 0.9±0.1 |
| Check | 39 | 0.9±0.1 | 2.0±0.2 | 0.1±0.0 |
| *Burkett* | | | | |
| Orchard 2 | | | | |
| Lead arsenate | 6 | 22.9±2.3 | 48.5±3.1 | 2.9±0.3 |
| Lead arsenate-Summer oil | 30 | 19.2±1.4 | 45.4±1.6 | 3.0±0.1 |
| Lead arsenate-Soybean flour | 12 | 18.9±2.2 | 34.5±2.3 | 2.1±0.0 |
| Check | 39 | 2.0±0.2 | 4.8±0.3 | 0.3±0.0 |
| *Halbert* | | | | |
| Lead arsenate | 6 | 22.6±7.0 | 50.0±9.8 | 5.5±0.6 |
| Lead arsenate-Summer oil | 4 | 34.7±2.6 | 60.2±3.7 | 5.6±0.3 |
| Check | 18 | 1.9±0.2 | 4.1±0.3 | 0.5±0.1 |
| *Humble* | | | | |
| Lead arsenate | 4 | 10.5±3.2 | 45.2±7.7 | 4.8±0.7 |
| Lead arsenate-Summer oil | 8 | 11.1±1.8 | 50.4±5.5 | 5.7±0.5 |
| Check | 7 | 0.9±0.2 | 3.6±0.9 | 0.4±0.1 |
| *Texas Prolific* | | | | |
| Lead arsenate-Summer oil | 5 | 12.4±2.2 | 53.5±3.1 | 5.3±0.4 |
| Lead arsenate-Sulfated alcohol | 10 | 8.4±1.3 | 45.7±5.4 | 3.5±0.3 |
| Check | 11 | 1.4±0.1 | 8.5±0.8 | 1.1±0.1 |

* Four pounds per 100 gallons; but in all other treatments 6 pounds.

On check trees of the Burkett and Humble varieties the nut casebearer destroyed on an average more than 80 per cent of the nuts and on the check trees of the Western Schley variety approximately 50 per cent. On Burkett variety pecans lead arsenate at the rate of six pounds per 100 gallons of water plus 1 gallon of summer oil gave reductions in infestation of 66.6, 75.5, and 85.6 per cent. Lead arsenate used at the same rate but without summer oil gave reductions of 56.2, 77.4, and 81.3 per cent. Cryolite without summer oil was much less effective than with the oil.

In the absence of treatment the nut casebearer destroyed many tagged clusters of nuts entirely, and reduced the average number per original cluster to 0.2 to 0.6 nuts each. The control of the nut casebearer resulting from certain of the lead arsenate treatments permitted the average retention of from 1.3 to 2.8 nuts per cluster.

All the insecticidal treatments increased nut yield. The largest yield was obtained from trees sprayed with lead arsenate at the rate of 6 pounds per 100 gallons and with this material in combination with summer oil.

At the end of the season hibernacula were about three times as abundant on check trees as on trees that had been sprayed with lead arsenate, 6 pounds, and summer oil, 1 gallon, to each 100 gallons of spray.—11-16-39.

# Habits of the Larvae of *Gasterophilus nasalis* (L.) in the Mouth of the Horse[1]

H. O. SCHROEDER, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

Published records concerning *Gasterophilus nasalis* (L.) give no definite information on the habits and habitat of the larvae from the time of their entry into the mouth of the horse as first-instar larvae until they appear in the duodenum in the second instar. Wells and Knipling (1938) have shown that the eggs hatch without special stimuli and that the larvae migrate down the skin surface into the mouth of the host. Dinulescu (1932) writes that larvae of *G. nasalis* penetrated the mucosa of the cheek in experimentally infested guinea pigs. Wells and Knipling (1938) failed to find them in this tissue in the horse, but, by noting their appearance in the duodenum as second-instar larvae within 17 to 24 days after they had hatched, concluded that this range represented the first stadium.

In 1938 experiments were undertaken at Ames, Iowa, (1) to recover first-instar larvae from the horse, (2) to discover what tissues are invaded by the first instar in the horse, (3) to determine the first stadium, and (4) to determine the larval development and the time spent in the host prior to arrival in the duodenum.

EGG COLLECTIONS.—The female of *Gasterophilus nasalis* deposits her eggs mainly on the hairs of the intermaxillary region. Egg-trap halters, such as those described by Wells and Knipling (1938), were used to facilitate the collection of large numbers of eggs. This device consisted of a piece of horsehide large enough to cover the lower jaw from chin to throat. The hide, tanned with the hair intact, was attached to a halter with the hair side out. The females oviposited readily on the hair when the halter was buckled into position on the horse's head. Eggs of a uniform age were obtained by limiting the exposure period of the halter. The hairs with eggs attached were clipped from the halter.

INCUBATION.—Eggs were incubated at 95.7 degrees F. in a constant-temperature cabinet. Incubation at a lower temperature produced less vigorous larvae. A relatively high humidity was maintained by placing pans of water in the cabinet.

In order to have as many eggs as possible ready to hatch on the day an infestation was to be made, it was found preferable to delay hatching of fully incubated eggs rather than to retard incubation. The hatching of fully incubated eggs was interrupted and delayed for as long as 10 days, with no apparent injury to the larvae, by maintaining them at 55 to 57 degrees F.

[1] Early publication of this paper has been secured by payment of the costs.

HANDLING OF NEWLY HATCHED LARVAE.—The method found to be most satisfactory for handling hatching eggs was as follows: A paper funnel about 3 inches high, 2 inches in diameter at the large end, and with a small hole at the bottom was set in a 250-cc. beaker. The eggs, still attached to the hairs, were placed in the funnel, and as the eggs hatched the larvae escaped through the opening at the bottom onto the floor of the beaker. The hairs were arranged more or less vertically to hasten the descent of the larvae. The newly hatched larvae were then transferred directly to the mucous membranes of the lips of the horse with the aid of a camel's-hair brush. A high percentage of the larvae enter the mouth of the host in good condition if the transfer is made within 15 minutes after the hatching.

INFESTING THE HOSTS.—Five horses, 10 to 20 years of age, were used as hosts in these experiments. Uncontrolled infestation was prevented by protecting the jaws from oviposition prior to and during the experiment. On the days infestations were made water and food were withheld from the host until one-half hour after the last larvae were introduced. The horses were kept for various periods subsequent to infestation and were then killed and examined for the presence of larvae.

Host No. 1 was grossly infested with all available larvae over a period of 36 days, primarily for the purpose of determining the habitat of the first-instar larvae. The location in the host having been established, it was expected that experimental infestations could be spaced at such intervals that the sizes of the larvae recovered would be indicative of their respective ages. Actually, however, in hosts Nos. 2 and 3 there was so much variation in growth of the larvae that recognition of their ages was impossible. To avoid this confusion, only one infestation was made in hosts Nos. 4 and 5.

RESULTS.—Dinulescu (1932) and Wehr (1933) have shown that the newly hatched larvae of *Gasterophilus intestinalis* (DeGeer) penetrate the dorsal surface of the tongue and usually tunnel the length of that organ before passing on to the stomach as second-instar larvae. Wells & Knipling (1938) have shown that the first-instar larvae of *G. haemorrhoidalis* (L.) penetrate the dermal and mucous layers of the lips. The post-mortem examinations of the five horses experimentally infested with newly hatched larvae of *G. nasalis* revealed the fact that the habits of this species differ markedly from those of *G. intestinalis* and *G. haemorrhoidalis*. When a close examination of the gum tissues was made, the larvae were found invading the spaces around and between the teeth below the gum line.

**Table 1.—Instars and locations of larvae of *Gasterophilus nasalis* recovered from experimentally infested horses.**

| Host No. | Number of Larvae Introduced | Larval Age at Post-mortem, Days | Number of Larvae Recovered | | | | Per Cent Recovered |
|---|---|---|---|---|---|---|---|
| | | | From Mouth | | From Duodenum | | |
| | | | First Instar | Second Instar | Second Instar | Total | |
| 1 | 1,234 | 1–36 | 96 | 2 | 27 | 125 | 10.1 |
| 2 | 1,360 | 1–22 | 77 | 12 | 12 | 101 | 7.4 |
| 3 | 1,499 | 9–35 | 114 | 10 | 37 | 161 | 10.7 |
| 4 | 264 | 17–18 | 19 | 6 | 4 | 29 | 11.0 |
| 5 | 203 | 24 | 2 | 9 | 7 | 18 | 8.9 |

The exposed crowns of the upper and lower cheek teeth normally lie in close contact, forming continuous rows. The imbedded portions, however, are narrower, and normally the interalveolar septa virtually fill the spaces between the teeth. In establishing themselves around the teeth the larvae are associated with a necrosis of the tissue involved. This results in the formation of pus pockets extending into the tooth sockets and involving the alveolar tissue between and around the teeth. Food particles lodging between loose teeth also increase the size of these pockets. As many as 12 larvae were removed from one pus pocket.

Maturing larvae of both the first and second instars were often found in the same pocket. Younger first-instar larvae

were sometimes found at the sides of the teeth, concealed by the gums, with no apparent lesion. The numbers and the instars of larvae recovered from the individual hosts are shown in table 1. A total of 347 larvae were recovered from the mouths of the five experimental horses. In every instance they were found between the teeth, well below the gum line or behind the alveolar process of the gum. In these locations the larvae were well protected and not easily dislodged. In a few instances the posterior tips of larvae were exposed to view momentarily. Generally, however, they were completely hidden, and it was necessary to probe behind the alveolar process of the gums or to cut away the gum to expose the larvae. Resection of a portion of the bone forming the sides of the tooth sockets was necessary to effect recovery of some of the larvae from between the teeth. No larvae were recovered from the mouth except as just described.

One of the horses was infested by placing all larvae between the lips near the left commissure. Subsequently 19 larvae were recovered from around the teeth on the right cheek, 16 from around those on the left, and 1 from near a front tooth. Distribution in the mouth is no doubt greatly affected by the normal movements of the lips, tongue, food, and saliva.

Host No. 5 was infested with 203 larvae. Twenty-four days later only 2 of the 18 larvae recovered were still in the first instar. These were apparently fully developed and ready to molt. Therefore it is reasonable to assume that 24 days approximates the maximum duration of the first larval stadium.

Second-instar larvae recovered from the mouth of the host showed a considerable variation in size, indicating a period of growth after the molt. It is evident therefore that some larvae do not leave the mouth until several days after the first molt. It is probable that some larvae of *Gasterophilus nasalis*, after invading the mouth, may remain there as long as 28 to 30 days.

Host No. 4 was infested with 264 larvae during 2 consecutive days and killed when these larvae were 18 and 17 days old. Only 10 of 29 larvae recovered had molted. Six of these second-instar larvae were still in the mouth, indicating that the minimum period in the mouth is not much less than 17 or 18 days.

SUMMARY.—Five horses were experimentally infested with newly hatched larvae of *Gasterophilus nasalis* (L.). Subsequent post-mortem examinations resulted in the recovery of both first- and second-instar larvae from the mouth. The larvae were found invading the spaces between the teeth below the gum line and behind the alveolar process of the gums. No larvae were found burrowing in any other mouth tissue. Necrosis of the tissue results from the presence of the larvae.

The larvae molt to the second instar and experience a short period of growth before passing to the duodenum.

The minimum and maximum durations of the first stadium approximate 18 and 24 days, respectively.—3-1-40.

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THE Bureau of Entomology and Plant Quarantine announces that the field headquarters for Mormon cricket control have been moved from Salt Lake City to Denver, and that the work has been consolidated with the grasshopper control project, the headquarters of which were moved from Minneapolis to that city in January of this year. The Denver offices of both projects are in the Insurance Exchange Building, 810-14th Street.

THE white-fringed beetle quarantine restrictions were modified on February 2, 1940, through administrative instructions of the Chief of the Bureau of Entomology and Plant Quarantine, which exempt from beetle certification soil-free potatoes until May 1, 1940, and soil-free sweetpotatoes until June 1, 1940, when consigned from any part of the regulated areas. The above modification was issued as the fourth revision of circular B.E.P.Q. 485.

# Control of the European Red Mite with Special Reference to Dinitro-o-Cyclohexylphenol in Dormant Sprays

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This paper consists principally of the results obtained from tests in which dinitro-o-cyclohexylphenol[2] (DNOCHP) was compared with other dormant ovicides against the eggs of the European red mite. *Paratetranychus pilosus* C & F. Results obtained with a number of miscellaneous materials in the delayed dormant period and with a summer oil are also reported.

The experimental results obtained by various workers on the control of the European red mite during the dormant period are in general agreement. Garman (1925) stated that miscible oils are effective dormant sprays and, with care, are reasonably safe in orchard work. Newcomer & Yothers (1927) reported that lubricating oil emulsions and miscible oils at dilutions of 2, 3, and 4 per cent of oil prevented more than 95 per cent of the eggs from hatching in most cases. In making a study of combined sprays for the control of the overwintering eggs of both the European red mite and apple aphids, Headlee & Ginsburg (1929) found that excellent results could be obtained by the use of oil emulsion and free nicotine, or oil emulsion and crude cresylic acid (0.5 per cent). In a recent bulletin Garman & Townsend (1938) recommended a dormant or delayed dormant application of 3 or 4 per cent actual oil. They found that there was a great reduction in the number of predators of the European red mite when oils containing cresylic acid or dinitro-o-cyclohexylphenol were employed. They also observed that the most serious outbreaks of the mites occurred in orchards following the use of tar oils. According to the recent experimental data of Worthley & Steiner (1939) dinitro-o-cyclohexylphenol had little effect upon European red mite eggs, and injury was obtained in every case where the DN oils were used.

Procedure.—A power sprayer was used in applying the dormant and delayed dormant sprays during the season 1935–36, except in one plot where a hand sprayer was used. Several trees were included in a single plot in the former case, but only one tree was included in the plot sprayed by hand. After hatching of the mite eggs was completed in late April or early May, small branches were cut at random from trees in each plot and brought to the laboratory where the eggs were examined under a binocular microscope to determine the number and percentage that had hatched. In one orchard (Nos. 1–8) it was necessary to collect the branches about the middle of March, but they were kept under outdoor conditions until the overwintering eggs had hatched. In 1938 the procedure was slightly changed. The branches were collected prior to spraying and brought into the laboratory where they were observed under a binocular microscope, and all of the remains of eggs previously hatched were marked off. The branches were then sprayed and placed outdoors until hatching was completed. In 1939 the same procedure was followed except that circumstances did not permit the examination of the branches prior to spraying. The percentages of control were calculated from Abbott's formula (Abbott 1925).

Experiments with Dinitro-o-Cyclohexylphenol.—Three types of preparations containing dinitro-o-cyclohexylphenol were used: The toxic material dissolved in petroleum oil; a dry-mix consisting of the toxic material and emulsifier for preparing a tank-mix oil emulsion; and a wettable powder. In the 1935–36 tests 4 ounces of dried sulfite waste, or lignin pitch (*Goulac*), and 12 ounces of bentonite per 100 gallons of diluted spray were used in emulsifying the oils containing dinitro-o-cyclohexylphenol, except in one case (No. 43) where 8 ounces of *Goulac* and 8 ounces of hydrated lime were used. In the 1938 and 1939 tests the emulsifier for the oils containing dinitro-o-cyclohexylphenol consisted of 5 ounces of *Goulac* and 15 ounces of bentonite per 100 gallons of diluted spray. In a few tests the dry-mix and the wettable forms of the toxic ma-

[1] The writer makes acknowledgment to Dr. W. S. Hough for guidance in carrying on this work, to Dr. W. J. Schoene for suggestions, and to Dr. J. A. Cox for applying the sprays for the 1939 season.

[2] This compound is more specifically 2,4-dinitro-6-cyclohexylphenol. It is unfortunate that the term dinitro-o-cyclohexylphenol is being used by entomologists, since several other isomeric forms of dinitro-o-cyclohexylphenol are theoretically possible and may in the future have insecticidal significance.

**Table 1.—Results of experiments with dormant and delayed dormant sprays against European red mite eggs, Winchester, Va.**

| Plot No. | Date Sprayed | Materials and Per Cent Concentration or Amount per 100 Gallons | Eggs Examined | Per Cent Hatched | Per Cent Control |
|---|---|---|---|---|---|
| A-1 | Jan. 13, 1936 | Oil[1] 3% tar distillate 2½% | 400 | 52.7 | 42.8 |
| 2 | Jan. 13, 1936 | Oil[2] 1.8% (DNOCHP 8.9 oz.) | 500 | 39.8 | 56.8 |
| 3 | Jan. 13, 1936 | Tar distillate[3] 1.65%, paraffin wax 0.66% | 300 | 84.6 | 8.3 |
| 4 | Jan. 13, 1936 | Oil[4] 2% | 300 | 79.9 | 13.4 |
| 5 | Jan. 13, 1936 | Oil[4] 3% | 400 | 60.5 | 34.4 |
| 6 | Mar. 9, 1936 | Oil[4] 2% | 400 | 84.2 | 8.7 |
| 7 | Mar. 9, 1936 | Oil[4] 3% | 300 | 40.9 | 55.6 |
| 8 | Mar. 18, 1936 | Water gas tar oil 2% | 300 | 81.6 | 11.5 |
| | | Check, not sprayed | 300 | 92.3 | |
| B-9 | Dec. 6, 1935 | Oil[1] 3%, tar distillate 2½% | 400 | 16.7 | 70.1 |
| 10 | Dec. 6, 1935 | Oil[2] 1.2% (DNOCHP 5.9 oz.) | 300 | 26.3 | 53.0 |
| 11 | Dec. 6, 1935 | Oil[2] 2.41% (DNOCHP 11.85 oz.) | 400 | 22.0 | 60.6 |
| 12 | Mar. 25, 1936 | Oil[2] 0.6% (DNOCHP 2.95 oz.) | 500 | 32.0 | 42.8 |
| 13 | Mar. 25, 1936 | Oil[2] 1.2% (DNOCHP 5.9 oz.) | 300 | 27.9 | 50.1 |
| 14 | Mar. 25, 1936 | Oil[2] 2.17% (DNOCHP 10.7 oz.) | 300 | 12.3 | 78.0 |
| 15 | Mar. 25, 1936 | Oil[1] 2.33%, tar distillate 1.93% | 300 | 12.6 | 77.4 |
| 16 | Mar. 25, 1936 | Miscible oil 2.11% (DNOCHP 9.1 oz.) | 300 | 21.6 | 61.4 |
| 17 | Mar. 25, 1936 | Oil[1] 3%, tar distillate 2½% | 300 | 11.6 | 80.1 |
| | | Check, not sprayed | 500 | 56.0 | |
| C-18 | Mar. 23, 1936 | Oil[2] 1.08% (DNOCHP 5.33 oz.) | 600 | 46.9 | 38.1 |
| 19 | Mar. 23, 1936 | Oil[2] 1.27% (DNOCHP 6.25 oz.) | 600 | 41.1 | 45.7 |
| 20 | Mar. 23, 1936 | Oil[2] 1.45% (DNOCHP 7.12 oz.) | 300 | 36.3 | 52.1 |
| 21 | Mar. 23, 1936 | Oil[2] 1.8% (DNOCHP 8.9 oz.) | 300 | 44.9 | 40.7 |
| 22 | Mar. 23, 1936 | Oil[2] 2.17% (DNOCHP 10.7 oz.) | 300 | 26.3 | 65.2 |
| 23 | Mar. 23, 1936 | Oil 1.5% (DNOCHP 7.14 oz.) | 312 | 27.2 | 64.1 |
| 24 | Mar. 23, 1936 | Oil 1.87% (DNOCHP 8.92 oz.) | 300 | 21.9 | 71.0 |
| 25 | Mar. 23, 1936 | Miscible oil 1.26% (DNOCHP 5.46 oz.) | 312 | 17.9 | 76.3 |
| 26 | Mar. 23, 1936 | Miscible oil 1.69% (DNOCHP 7.28 oz.) | 300 | 21.9 | 71.0 |
| 27 | Mar. 23, 1936 | Tar distillate[3] 1.92%, paraffin wax 0.77% | 300 | 50.6 | 33.2 |
| 28 | Mar. 23, 1936 | Tar distillate[3] 2.2%, paraffin wax 0.88% | 300 | 37.3 | 50.7 |
| 29 | Mar. 23, 1936 | Oil[1] 3% and tar distillate 2½% | 305 | 19.6 | 74.1 |
| 30 | Mar. 23, 1936 | Oil[5] 2% | 616 | 44.4 | 41.4 |
| 31 | Mar. 23, 1936 | Oil[5] 3% | 500 | 23.4 | 69.1 |
| 32 | Mar. 23, 1936 | Oil (100 sec. vis.) 2% | 793 | 23.8 | 68.5 |
| 33 | Mar. 23, 1936 | Oil (100 sec. vis.) 3% | 563 | 17.5 | 76.8 |
| 34 | Mar. 23, 1936 | Oil (150 sec. vis.) 2% | 300 | 30.9 | 59.2 |
| 35 | Mar. 23, 1936 | Water-gas tar oil 2½%, oil 2½% | 326 | 42.3 | 44.1 |
| 36 | Mar. 23, 1936 | Water-gas tar oil 2%, oil 2½% | 300 | 36.6 | 51.7 |
| 37 | Mar. 23, 1936 | Water-gas tar oil 3½% | 300 | 33.3 | 56.0 |
| | | Check, not sprayed | 600 | 75.8 | |
| D-38 | Dec. 5, 1935 | Oil[2] 0.6% (DNOCHP 2.95 oz.) | 88 | 30.6 | 39.1 |
| 39 | Dec. 5, 1935 | Oil[2] 1.2% (DNOCHP 5.9 oz.) | 151 | 32.4 | 35.5 |
| 40 | Dec. 5, 1935 | Oil[2] 2.41% (DNOCHP 11.85 oz.) | 113 | 23.9 | 52.4 |
| 41 | Dec. 5, 1935 | Oil[1] 2½%, tar distillate 2% | 116 | 18.1 | 64.0 |
| 42 | Dec. 5, 1935 | Oil[1] 3%, tar distillate 2½% | 131 | 17.5 | 65.2 |
| 43 | Dec. 5, 1935 | Oil 0.63% (DNOCHP 3.01 oz.) | 398 | 29.9 | 40.5 |
| 44 | Mar. 26, 1936 | Oil 1% (DNOCHP 4.76 oz.) | 261 | 14.5 | 71.1 |
| 45 | Mar. 26, 1936 | Oil[2] 1.2% (DNOCHP 5.9 oz.) | 300 | 11.6 | 76.9 |
| 46 | Mar. 26, 1936 | Oil[2] 2.17% (DNOCHP 10.7 oz.) | 213 | 8.9 | 82.3 |
| 47 | Mar. 26, 1936 | Miscible oil 1.4% (DNOCHP 6.04 oz.) | 456 | 15.7 | 68.7 |
| 48 | Mar. 26, 1936 | Oil[1] 2½%, tar distillate 2% | 201 | 7.4 | 85.0 |
| | | Check, not sprayed | 169 | 50.3 | |
| E-49 | Apr. 6–7, 1936 | Oil 2½%, nicotine sulphate 0.125% | 300 | 6.9 | 89.4 |
| 50 | Apr. 6–7, 1936 | Oil 2½%, cresylic acid 0.5% | 464 | 13.1 | 79.9 |
| 51 | Apr. 6–7, 1936 | Oil 2½% | 300 | 12.3 | 81.1 |
| 52 | Apr. 6–7, 1936 | Lime sulphur 2½%, nicotine sulphate 0.125% | 300 | 22.3 | 65.8 |
| 53 | Apr. 6–7, 1936 | Cresylic acid 0.5% | 300 | 51.9 | 20.6 |
| | | Check, not sprayed | 345 | 65.4 | |

[1] Prepared from an emulsion containing 46.5% petroleum oil and 38.5% tar oil (creosote oil).
[2] Prepared from an emulsion containing 72% petroleum oil.
[3] Prepared from an emulsion containing 55% tar oil (creosote oil) and 22% paraffin wax.
[4] Prepared from an emulsion containing 66% petroleum oil.
[5] Prepared from an emulsion containing 83% petroleum oil.

**Table 2.—Results of experiments with dormant sprays against European red mite eggs, Blacksburg, Virginia.**

| PLOT NO. | DATE SPRAYED | MATERIALS AND PER CENT CONCENTRATION OR AMOUNT PER 100 GALLONS | EGGS EXAMINED | PER CENT HATCHED | PER CENT CONTROL |
|---|---|---|---|---|---|
| | *1938* | *College Orchard* | | | |
| 54 | Mar. 14 | Oil[1] 1½% | 227 | 8.3 | 71.4 |
| 55 | Mar. 14 | Oil[1] 2% | 243 | 4.1 | 85.9 |
| 56 | Mar. 14 | Oil[1] 3% | 230 | 2.1 | 92.7 |
| 57 | Mar. 14 | Oil[1] 2%, wettable DN 0.476 lb. (DNOCHP 7.5 oz.) | 220 | 2.7 | 90.7 |
| 58 | Mar. 14 | Oil[1] 2%, wettable DN 0.63 lb. (DNOCHP 9.8 oz.) | 288 | 1.7 | 94.1 |
| 59 | Mar. 14 | Oil[1] 2%, wettable DN 0.736 lb. (DNOCHP 11.5 oz.) | 258 | 3.1 | 89.3 |
| 60 | Mar. 14 | Oil 1½%, dry-mix 1.33 lbs. (DNOCHP 7.4 oz.) | 208 | 2.4 | 91.7 |
| 61 | Mar. 14 | Oil 2%, dry-mix 1.75 lbs. (DNOCHP 9.8 oz.) | 235 | 4.2 | 85.5 |
| 62 | Mar. 14 | Dry-mix (D-23) 1.75 lbs. (DNOCHP 7.5 oz.) | 298 | 7.3 | 74.9 |
| 63 | Mar. 14 | Oil 1½%, dry-mix (D-23) 1.75 lbs. (DNOCHP 7.5 oz.) | 260 | 2.3 | 92.0 |
| 64 | Mar. 14 | Oil 2%, dry-mix (D-23) 1.75 lbs. (DNOCHP 7.5 oz.) | 291 | 6.1 | 79.0 |
| 65 | Mar. 15 | Oil 1½% (DNOCHP 7.14 oz.) | 343 | 7.5 | 74.2 |
| 66 | Mar. 15 | Oil 2% (DNOCHP 9.5 oz.) | 329 | 7.2 | 75.2 |
| 67 | Mar. 15 | Oil 1½%, lauryl rhodanate 0.4% | 220 | 3.1 | 89.3 |
| 68 | Mar. 15 | Oil 2%, lauryl rhodanate 0.4% | 293 | 3.0 | 89.6 |
| 69 | Mar. 15 | Oil[2] 3%, tar distillate 2½% | 349 | 2.8 | 90.3 |
| | | Check, not sprayed | 326 | 29.1 | |
| | *1939* | *College Orchard* | | | |
| 70 | Mar. 8 | Oil (121 sec. vis.) 3% | 331 | 23.2 | 61.2 |
| 71 | Mar. 8 | Oil (121 sec. vis.) 4% | 275 | 5.4 | 90.9 |
| 72 | Mar. 8 | Oil (121 sec. vis.) 5% | 700 | 5.1 | 91.4 |
| 73 | Mar. 8 | Oil (166 sec. vis.) 2% | 300 | 21.0 | 64.9 |
| 74 | Mar. 8 | Oil (166 sec. vis.) 3% | 576 | 10.5 | 82.4 |
| 75 | Mar. 8 | Oil (166 sec. vis.) 4% | 300 | 13.3 | 77.7 |
| 76 | Mar. 8 | Oil (166 sec. vis.) 5% | 400 | 11.7 | 80.4 |
| 77 | Mar. 8 | Wettable D-29 1 lb. (DNOCHP 8.0 oz.) | 450 | 26.4 | 55.9 |
| 78 | Mar. 8 | Wettable D-29 1½ lbs. (DNOCHP 12.0 oz.) | 263 | 38.4 | 35.8 |
| 79 | Mar. 8 | Wettable D-24 1¾ lbs. (DNOCHP 10.0 oz.) | 330 | 54.2 | 9.5 |
| 80 | Mar. 8 | Wettable D-24 2½ lbs. (DNOCHP 14.3 oz.) | 500 | 45.0 | 24.8 |
| 81 | Mar. 8 | Oil[2] 2.13% (Dinitro-phenol 8.0 oz.) | 400 | 8.5 | 85.8 |
| 82 | Mar. 8 | Oil[2] 2½% (Dinitro-phenol 9.3 oz.) | 324 | 7.0 | 88.3 |
| 83 | Mar. 8 | Oil[4] 2¼% (Toxicant 0.03%) | 235 | 34.0 | 43.2 |
| 84 | Mar. 8 | Oil[4] 3% (Toxicant 0.04%) | 660 | 18.7 | 68.7 |
| 85 | Mar. 8 | Oil 2% (DNOCHP 9.5 oz.) | 392 | 18.6 | 68.9 |
| 86 | Mar. 8 | Oil 3% (DNOCHP 14.3 oz.) | 290 | 11.0 | 81.1 |
| 87 | Mar. 8 | Miscible oil 2% (DNOCHP 7.3 oz.) | 230 | 15.6 | 73.9 |
| 88 | Mar. 8 | Miscible oil 3% (DNOCHP 11.0 oz.) | 273 | 8.0 | 86.6 |
| 89 | Mar. 8 | Miscible oil 2% (DNOCHP 9.7 oz.) | 400 | 11.7 | 80.4 |
| 90 | Mar. 8 | Miscible oil 3% (DNOCHP 14.6 oz.) | 500 | 10.0 | 83.3 |
| 91 | Mar. 8 | Oil[2] 3%, tar distillate 2½% | 146 | 10.2 | 82.9 |
| 92 | Mar. 8 | Oil (121 sec. vis.) 3%, wettable D-24 1¾ lbs. (DNOCHP 10.0 oz.) | 490 | 14.8 | 81.9 |
| 93 | Mar. 8 | Oil (121 sec. vis.) 3%, wettable D-29 1 lb. (DNOCHP 8.0 oz.) | 400 | 15.7 | 73.7 |
| | | Check, not sprayed | 554 | 59.9 | |

[1] Prepared from an emulsion containing 83% petroleum oil.
[2] Prepared from an emulsion containing 46.5% petroleum oil and 38.5% tar oil (creosote oil).
[3] Prepared from an emulsion containing 71% petroleum oil.
[4] Prepared from an emulsion containg 75% petroleum oil with toxicant composed of trinitro-phenol and trinitro-toluene.

terial were used without the addition of petroleum oil. The amounts of dinitro-o-cyclohexylphenol used in the various sprays are shown in tables 1 and 2.

There are two factors which may have contributed to the low percentages of control obtained with the various sprays: The remains of eggs that had already hatched were removed before the sprays were applied in 1938, but were not in other years; and there was a variation in the hatching of the eggs, the percentages in some checks being sufficiently low to decrease considably the percentage of control as determined by Abbott's formula.

A study of the data shown in tables 1 and 2 reveals that petroleum oil containing dinitro-o-cyclohexylphenol is slightly more effective in killing the overwintering eggs of the European red mite than pe-

troleum oil when used alone. Less than 2 per cent oil with 7 to 9 ounces of DNOCHP in 100 gallons (Nos. 24 and 26) gave control comparable to 3 per cent oil alone (No. 31) and with tar distillate (No. 29). Oil, 1½ per cent (No. 60), with 7.4 ounces of DNOCHP per 100 gallons and oil, 2 per cent, with 7.5 and 9.8 ounces of DNOCHP per 100 gallons (Nos. 57 and 58) gave control comparable to that of 3 per cent oil alone (No. 56) and with tar distillate (No. 69). A spray containing 2 per cent oil with 9.7 ounces of DNOCHP per 100 gallons (No. 89) was almost as effective as 3 per cent oil (No. 74).

Dinitro-o-cyclohexylphenol in the drymix or the wettable powder form, when used alone, is relatively ineffective as an ovicide against the European red mite. Only 35.8 per cent control was obtained with 12 ounces of DNOCHP, as a wettable powder, per 100 gallons (No. 78), and only 24.8 per cent control was obtained with another form of wettable powder (No. 80) used at the rate of 14.3 ounces per 100 gallons.

EXPERIMENTS WITH OTHER MATERIALS.—A standard dormant insecticide consisting of a combination of petroleum oil and tar distillate in the form of an emulsion was included in most of the series of sprays. The control obtained with 3 per cent of petroleum oil and 2.5 per cent of tar distillate was about equal to that of the other effective combinations tested (Nos. 17, 29, 69, and 91).

The ineffectiveness of the water-gas tar oils and of a combination of tar distillate and paraffin wax as ovicides against the European red mite is evident in tests Nos. 3, 8, 27, 28, and 37.

Petroleums oils of various viscosities were applied as sprays. These were emulsified by the use of 4 ounces of *Goulac* and 12 ounces of bentonite per 100 gallons of diluted spray in Nos. 32, 33, 34 and 51. In the sprays for 1938 and 1939, 5 ounces of *Goulac* and 15 ounces of bentonite per 100 gallons of diluted spray were used for emulsifying the petroleum oils. The results obtained from the use of 3 per cent, or more, of petroleum oil compare favorably with those obtained with other effective materials.

In two tests petroleum oil containing dinitro-phenol (Nos. 81 and 82) gave 85 and 88 per cent control.

Petroleum oil emulsion containing trinitro-phenol and trinitro-toluene (Nos. 83 and 84) was ineffective as an ovicide.

Lauryl rhodonate, 0.4 per cent, with 1½ per cent petroleum oil and 2 per cent petroleum oil (Nos. 67 and 68) gave 89.3 and 89.6 per cent control, respectively.

EFFECT OF TIME OF APPLICATION.—During the dormant season of 1935–36, sprays were applied in December, January, March, and April to determine the influence of the time of application upon the effectiveness of each of the materials. Petroleum oil and tar distillate (Nos. 9 and 41) applied on December 5 and 6 gave 70.1 and 64.0 per cent controls, but when applied on March 25 and 26 (Nos. 17 and 48) gave 80.1 and 85.0 per cent controls. Petroleum oil with dinitro-o-cyclohexylphenol (Nos. 11 and 40) applied on December 5 and 6 gave 60.6 and 52.4 per cent controls, but sprays containing less oil and dinitro-o-cyclohexylphenol (Nos. 14 and 46) applied March 25 and 26 gave 78.0 and 82.3 per cent controls. The application of oil and nicotine sulphate (No. 49) as a delayed dormant spray in early April gave 89.4 per cent control.

SUMMER APPLICATION OF OIL.—During the summer of 1936 an outbreak of the European red mite occurred in an orchard near Rada, West Virginia. The injury by mites was most severe on a Delicious apple tree, although a block of Romes showed some injury. On July 9 an examination of 10 leaves selected at random revealed a total of 1090 live mites and 2919 eggs. A spray consisting of 6 quarts of an 83 per cent summer oil emulsion (light-medium grade) per 100 gallons was applied on July 13. No live mites were found in an examination of 10 leaves made a few hours after the spray was applied. Only 1 live mite and no eggs were found on 15 leaves examined July 25, while 20 live mites and no eggs were observed on 15 leaves examined August 24.

SUMMARY.—The ovicidal effectiveness of petroleum oil against European red mite eggs was slightly increased by the addition of dinitro-o-cyclohexylphenol. Sprays consisting of 2 per cent petroleum oil and dinitro-o-cyclohexylphenol in concentrations of not less than 8.0 ounces per 100 gallons of spray, in most cases, gave control comparable to that obtained with 3 per cent petroleum oil alone.

Dinitro-o-cyclohexylphenol, when used

as a wettable powder without petroleum oil, was ineffective as an ovicide.

Water-gas tar oils and combinations of tar distillate and paraffin wax were ineffective.

Sprays applied in December and January were not as effective against European red mite eggs as those applied in March or April.

Satisfactory control of an outbreak of the European red mite was obtained in July by the application of 6 quarts of 83 per cent summer oil emulsion per 100 gallons.—11-30-39.

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# The Repellency of Pyrethrin Dusts to the Beet Leafhopper on Tomatoes[1]

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It is exceedingly difficult to produce tomatoes on a commercial scale in many agricultural sections of Idaho because of a disease known as western yellow tomato blight. This disease is caused by the virus that causes curly top in sugar beets and many other plants such as cucumbers, beans, zinnias, etc. The beet leafhopper is, to date, the only known vector of the virus. In recognition of the potential importance of tomatoes as a commercial field crop in many sections of Idaho subjected to heavy leafhopper populations, investigations of potential leafhopper insecticides were conducted in the greenhouse at the University of Idaho during the winter of 1937 and under field conditions in the experimental plots of the Idaho Agricultural Experiment Station at Buhl, Idaho, the following spring and summer. During the course of the investigations, attention centered around the use of pyrethrin as a repellent.

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GREENHOUSE EXPERIMENTS.—In the Twin Falls district of southern Idaho, contact insecticides do not give much promise of controlling the beet leafhopper, because of constant migration from large surrounding abandoned farm and desert breeding areas into the cultivated districts. Douglass, *et al.* (1939) showed that applications of pryethrum to sugar beets in the field reduced the leafhopper populations at the time of spray application, but that migrations into the field occurred after such applications. The migratory habits of the insects at once suggests the use of repellent materials that would prevent feeding and introduction of the virus into the plant.

Pepper & Haenseler (1939) showed that pyrethrum dusts and rotenone dusts were effective in reducing infestations of the aster leafhopper, *Macrosteles divisus*, a vector of lettuce yellows. However, this material was used as a contact insecticide directed specifically against the nymphs.

MATERIALS AND METHODS.—The adult beet leafhoppers used throughout these

experiments were collected from sugar beets and mustard in southern Idaho during the fall of 1938. The collected leafhoppers were placed in cages each containing a growing beet plant and kept in a greenhouse until needed.

As it was necessary to apply known weights of dust to the tomato plants, a precision dust gun was made from plans published by Elmore, *et al*, (1935).

Potted tomato plants to be dusted were first placed on a stand 14 inches square with a circular hole 4 inches in diameter cut in the center. The stand was covered with a sponge rubber mat with a hole in the center slightly smaller in diameter than the outside of a 4 inch flower pot. The beaded rim of the pot rested securely on the mat. Over the plant was placed a large glass bell jar, the base of the jar resting on the mat. The nozzle of the dust gun was inserted into the bell jar through a hole near the top. A known weight of dust was placed in the gun and expelled gradually into the dusting chamber under twenty pounds of air pressure. This method of dusting gave excellent coverage on both upper and lower leaf surfaces.

The repellency cages were 3 feet long, 10 inches wide and 14 inches high. The top, ends and back of each cage were covered with cotton scrim and the front with celluloid. The base was constructed of boards in which two circular holes 4 inches in diameter were bored, one near each end. These were for the insertion of the pots, so the beaded rims would rest on the base, thus preventing the escape of leafhoppers. The top was removable, being held in place by four hooks. The frame was so constructed that a sliding sheet of galvanized iron could be inserted in the middle of the cage to divide it into two separate compartments to prevent the dispersion of the leafhoppers in the cage at the termination of each test period. Four holes were made in the back of the cage for the introduction and removal of the leafhoppers.

The preparation of diatomaceous earth and *Pyrocide 20* dusts consisted of measing the correct volumes of *Pyrocide 20* into a DeVilbiss atomizer and atomizing it into the dust through a small hole in the cap of a pint fruit jar. The jar was then vigorously shaken to insure a complete and thorough mixture.

The preparation of *Dry Pyrocide* and diatomaceous earth dusts consisted of measuring the correct amounts of the two materials and thoroughly mixing.

In each test, tomato plants were dusted by the method outlined above and a treated plant transferred to one end of the repellency cage. In the other end was placed an untreated tomato plant. The arrangement of the test plants was alternated in each succeeding cage to eliminate the effect of plant position in the cage. The top was closed and 50 adult female leafhoppers introduced into the center of the cage. The leafhoppers then selected the plants on which to feed and at the end of the test period the numbers on each plant were counted, and all leafhoppers removed from each cage. Each material was tested in from two to five separate cages.

To test the length of time over which the pyrethrins remained effective, the above procedure was used with the following deviations. The treated and untreated plants first introduced into the repellency cage constituted the test plants for the duration of the experiment. Every 24 hours the leafhoppers on each plant were counted, and removed and a new supply introduced.

The number of leafhoppers found feeding on the plants in each experiment was used as the criterion of repellency. Any leafhopper occurring on a plant at the end of the experiment was counted as feeding.

The *Pyrocide 20* and *Dry Pyrocide* were secured from McLaughlin Gormley King Co. The diatomaceous earth was secured from the Kittitas Diatomite Co. of Ellensburg, Washington.

PRESENTATION OF DATA.—Table 1 presents a condensed compilation of the data obtained during the tests. In experiment 1, diatomaceous earth was applied at the rate of 16.8 pounds per acre or 2.8 grams per plant. After 24 hours no leafhoppers were feeding on the treated plant but 44 were feeding on the untreated plant. The results of this experiment indicated that a heavy deposit of inert dust applied to tomato plants is repellent. Repeated tests, with the same material indicated that it was only partially effective.

In experiment 3, *Pyrocide 20* was incorporated into diatomaceous earth to make a pyrethrin concentration of 0.27 per cent and tested for 24 hours. Com-

plete protection to the treated plants was afforded by this dilution.

To determine the minimum pyrethrin content that may afford complete protection for 24 hours, experiments 4 to 7 inclusive were conducted. These indicated 0.23 per cent pyrethrins as the minimum effective dilution.

**Table 1.—Per cent beet Leafhoppers feeding on plants treated with dusts of pyrethrins and diatomaceous earth. Greenhouse tests with tomatoes.**

| TEST NO. | MATERIAL | GRAMS PER PLANT | PER CENT PYRETHRINS | EXPOSURE HOURS | INSECTS ON DUSTED PLANTS |
|---|---|---|---|---|---|
| 1 | Diatomaceous Earth alone | 2.8 | 0 | 24 | 0.00% |
| 2 | same | 2.8 | 0 | 24 | 9.06 |
| 3 | *Pyrocide-20* | 2.8 | 0.27 | 24 | 0.00 |
| 4 | same | 2.8 | 0.14 | 24 | 2.36 |
| 5 | same | 2.8 | 0.16 | 24 | 20.44 |
| 6 | same | 2.8 | 0.20 | 24 | 8.51 |
| 7 | same | 2.8 | 0.23 | 24 | 0.00 |
| 9 | same | 2.8 | 0.23 | 48 | 0.00 |
| 10 | same | 2.8 | 0.23 | 72 | 3.70 |
| 11 | same | 2.8 | 0.23 | 96 | 8.00 |
| 12 | same | 2.8 | 0.23 | 120 | 25.00 |
| 13 | *Dry Pyrocide* | 2.8 | 0.23 | 24 | 0.00 |
| 14 | same | 2.8 | 0.23 | 48 | 0.00 |
| 15 | same | 2.8 | 0.23 | 72 | 0.00 |
| 16 | same | 2.8 | 0.23 | 96 | 0.00 |
| 17 | same | 2.8 | 0.23 | 120 | 15.00 |
| 18 | *Pyrocide-20* | 2.8 | 0.27 | 24 | 0.00 |
| 19 | same | 2.8 | 0.27 | 48 | 0.00 |
| 20 | same | 2.8 | 0.27 | 72 | 0.00 |
| 21 | same | 2.8 | 0.27 | 96 | 10.53 |
| 22 | *Dry Pyrocide* | 2.8 | 0.27 | 24 | 0.00 |
| 23 | same | 2.8 | 0.27 | 48 | 0.00 |
| 24 | same | 2.8 | 0.27 | 72 | 0.00 |
| 25 | same | 2.8 | 0.27 | 96 | 10.00 |
| 26 | *Pyrocide-20* | 1.4 | 0.23 | 24 | 2.08 |
| 27 | same | 1.4 | 0.23 | 48 | 12.27 |
| 28 | *Dry Pyrocide* | 1.4 | 0.23 | 24 | 1.35 |
| 29 | same | 1.4 | 0.23 | 48 | 21.18 |

As pyrethrins are unstable when exposed to light and air, tests of the period of effectiveness of a pyrethrin-diatomaceous earth dust were made. *Pyrocide 20*, a liquid, and *Dry Pyrocide*, a standardized, stabilized dust were used in these tests.

The results of the use of *Pyrocide 20* dust, containing 0.23 per cent pyrethrins, are presented in experiments 8 to 12 inclusive. This material was effective for 24 hours but not for 72 hours. Experiments 13 to 17 inclusive followed the above tests. The effectiveness of *Dry Pyrocide* lasted 96 hours but not for 120 hours, or approximately 48 hours longer than for *Pyrocide 20* under greenhouse conditions. The above experiments were then duplicated using 0.27 per cent pyrethrins in experiments 18 to 21 inclusive, for *Pyrocide 20*, and experiments 22 to 25 inclusive for *Dry Pyrocide*. These seemed to indicate that *Dry Pyrocide* will not be effective for more than 24 hours longer than a *Pyrocide 20* dust of the same pyrethrin content.

The results of the next series of four experiments indicated that application of one-half the amount of dust 1.4 grams per plant, containing the proportions of pyrethrins used in the preceding experiments, cannot be relied upon to give protection for 24 hours.

FIELD EXPERIMENTS; MATERIAL AND METHODS.—Two varieties of tomatoes, namely Stone and Earlianna, were seeded in flats in the greenhouse on March 15, 1938. The seedlings were left undisturbed in a cool part of the greenhouse until April 12 to 13 at which time 250 plants of each variety were transplanted into individual potting cups and left undisturbed until May 26, when they were transplanted into the field. The planting contained 4 rows of 80 plants each. The plants were set 4 feet apart in each direction. The varieties were alternated in rows, the first one being Stone.

Plot 1 contained the first 15 plants of each row, thus including 60 plants—30 of the Stone and 30 of the Earlianna variety. Plots 2 and 3 contained the next 15 plants of each row, successively. Plot 4 contained the remaining 35 plants in each row, making a total of 320 plants.

Plot 1 was treated with *Dry Pyrocide* incorporated in diatomaceous earth, the dust containing 0.27 per cent pyrethrins and Plot 2 was treated with *Pyrocide 20* in diatomaceous earth at the same pyrethrin concentration. Plot 3 was left untreated as the check and Plot 4 contained plants treated with either *Dry Pyrocide* or *Pyrocide 20* and some untreated plants. The first and third rows of Plot 4 were treated in the following manner: first plant, *Pyrocide 20* dust; second plant, *Dry Pyrocide* dust; third plant, untreated; fourth plant, *Pyrocide 20* dust; etc. The second and fourth rows began with the *Dry Pyrocide* dust and followed the above order of treatment.

The pyrethrin dusts used in these experiments were prepared in the following manner. The *Dry Pyrocide* and diatomaceous earth were mixed directly together and rolled in a common milk can in which had been placed a few small stones to aid in mixing. In preparing the *Pyrocide 20* dust, the diatomaceous earth was put into the milk can, the lid fastened on and the liquid extract of pyrethrum atomized into the dust while the can was revolving. A special opening was made in the center of

the lid of the mixing can to admit the nozzle of the atomizer. Each dust was mixed in the revolving can for a period of 30 minutes to insure thorough mixing. These mixed dusts were allowed to stand in tight containers for not more than one week before using.

As each plant was to be dusted in the field, it was first covered with an ordinary 25 gallon lard can having a hole in the bottom of a diameter slightly larger than the nozzle of the Root hand duster used. The nozzle of the duster was inserted into this opening, the dust introduced into the closed area and the can removed. This method is similar to that used in the greenhouse and resulted in excellent and heavy coverage of the plants, until they became too large. At this period it was difficult to cover all portions of the plants and it was usually necessary to redust small portions after the cover was removed. Dusting by this method required approximately 31 pounds of dust per acre.

DISCUSSION OF DATA.—Transplanting of the individually cupped tomato plants was done on the evening of May 26, after the heat of the day, to enable the plants better to adapt themselves to field conditions and to prevent wilting. This was after leafhopper activity had ceased for the day, thereby enabling the plants to escape infection before a dust could be applied. Before leafhopper activity began on the following day, Plots 1, 2 and 4 were dusted with their respective materials.

In the late afternoon of May 27, a moderately severe wind storm arose which completely removed all visible traces of dust from the plants. This difficulty was encountered throughout this work and, due to the action of wind and rain, it was impossible to keep the plants continually covered with dust, thereby often affording the leafhoppers opportunity to feed before it was possible to make another application.

Greenhouse experiments showed that the dusts used were not effective after a period of four days for the pyrethrin dusts. Therefore, dusting was done every fourth day or whenever weather conditions permitted after this period had elapsed.

At different times during the summer, population counts were made in the plots. These were made with a Hill standardized sampler immediately before dust was applied to the plants. The results of the counts indicated a quite general distribution of leafhoppers over all the plots, which, from their habit, is to be expected. However, these counts are of significance only to illustrate the sporadic distribution of leafhoppers in such plantings.

Symptoms of blight did not appear in any of the plots until June 18 and the symptoms then were limited to purple venation. On June 28 the first disease counts were made and the data show a small number of diseased plants occurring in all plots. Undoubtedly, some of the plants were infected earlier in the season, the symptoms not appearing until at this time because of cold weather which prevailed until July.

A general survey of the plots was made again on July 6. Since the time of the last dusting, symptoms had appeared to a much greater extent, several plants being in the last stages of life and many severely diseased. Only those plants which apparently were in a healthy condition were dusted on July 6 and succeeding dates.

A second disease count was made on July 13. A great many more plants had become diseased, many severely, and many had died. Hot weather undoubtedly had accelerated disease development.

A third disease count made on July 21, showed a surprisingly large number of plants severely diseased and dead. At this time there were six healthy plants in Plot 1; four in Plot 2; none in Plot 3; and four in Plot 4. A greater percentage of healthy plants was in Plot 1 than in any of the other plots.

On July 21 there was an average of only five healthy plants in Plots 1 and 2 and none in the check, where all were dead or severely diseased. Plot 4 contained many dead and diseased plants, but appeared better than the check and not so good as the complete block treatments.

On July 27 no healthy plants were visible in any of the plots. The percentages of living but diseased plants in each of the plots were as follows: Plot 1, 40 per cent; Plot 2, 21.67 per cent; Plot 3, 1.67 per cent and Plot 4, 21.42 per cent.

It is interesting to note here that those plots dusted with *Dry Pyrocide* consistently exhibited higher percentages of healthy plants than plots receiving other treatments up until July 27, when all plants in all plots were dead or diseased,

and that *Pyrocide 20* offered more protection to the plants in the solidly dusted block than in the staggered treatment as in Plot 4 which contained plants dusted with either material and plants untreated.

SUMMARY AND CONCLUSIONS; FIELD EXPERIMENTS.—The application of *Dry Pyrocide* and *Pyrocide 20* incorporated into diatomaceous earth did not prevent, under field conditions, the feeding of the beet leafhopper on tomatoes.

The application of pyrethrum dusts to tomato plants has some effect in preventing the feeding of *E. tenellus*, it being possible to distinguish readily between the treated and untreated plots in the field.

An activated dust of *Dry Pyrocide* in diatomaceous earth appears to be more effective than a similar dust of *Pyrocide 20* having the same pyrethrin content.

The application of dusts to tomato plants did not apparently hinder growth or prevent pollination or the setting of fruit.

SUMMARY AND CONCLUSIONS; GREENHOUSE EXPERIMENTS.—Diatomaceous eath is partially effective in preventing the feeding of *Eutettix tenellus*.

*Pyrocide 20* and *Dry Pyrocide* incorporated in diatomaceous earth are effective in entirely preventing the feeding of *E. tenellus* on tomatoes for 72 to 96 hours respectively.

A pyrethrin content of 0.23 per cent was determined as the minimum concentration at which these two substances can be relied upon to give complete controls in the greenhouse.

The period of effectiveness of *Dry Pyrocide* and *Pyrocide 20* in diatomaceous earth, at the same percentage of pyrethrins, is approximately the same, differing not more than a few hours.—7-30-39.

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# Costs of Control Measures for the Citrus Rust Mite

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In Florida, the citrus rust mite (*Phyllocoptes oleivorus* Ashm.) is controlled almost entirely by applications to trees and fruits of sulfur in sprays or dusts. The sprays may contain lime sulfur solution, wettable sulfur, dry lime sulfur, or combinations of these materials, and conditioned dusting sulfurs of different fineness and purity are applied in dry form. Most of these sulfur sprays and dusts are effective against rust mites and in preventing russeting, but some are effective over longer periods of time than others. The differences in cost between different materials and spray programs are important to growers. The cost is affected by the price of insecticides that make up the treatment, the method of application, labor, and equipment depreciation costs, quantity of material applied, and the number of applications per season.

SOURCE OF COST DATA.—Many experiments involving groves have been conducted at the Orlando, Florida, laboratory during the last four years to improve control methods used against the rust mite on orange trees. In this work accurate records were kept of the cost of materials, the average amount of material per tree for each application, and the number of applications necessary per season for adequate control. The treatments for which cost data are given were selected from various rust mite experiments carried on from 1936 to 1939, inclusive, and information is given only on more or less standard sulfur spray mixtures and sulfur dusts which have been

[1] Acknowledgment is due Herbert Spencer for helpful criticism during the preparation of this paper.

**Table 1.—Costs of rust-mite control on orange trees, Orlando, Fla., 1936–39.**

| Treatment* | Year | Grove No.† | Material, Gallons per Tree per Application | Applications Required | Total Cost per Tree |
|---|---|---|---|---|---|
| *Sprays* | | | | | |
| Lime sulfur 2 gal. | 1936 | 1 | 6.5 | 3 | $0.25 |
| | 1937 | 1 | 8.3 | 5 | 0.53 |
| | 1937 | 2 | 8.7 | 4 | 0.45 |
| | 1938 | 1 | 7.1 | 4 | 0.36 |
| | 1938 | 2 | 5.9 | 5 | 0.38 |
| | 1939 | 1 | 7.4 | 3 | 0.28 |
| Lime sulfur 2 gal.+wettable sulfur (325-mesh) 10 lb. | 1936 | 1 | 6.5 | 2 | 0.21 |
| | 1937 | 1 | 8.2 | 4 | 0.53 |
| | 1937 | 2 | 6.8 | 3 | 0.33 |
| | 1938 | 1 | 7.0 | 4 | 0.46 |
| | 1938 | 2 | 6.7 | 4 | 0.44 |
| Lime sulfur 1 gal.+wettable sulfur (325 mesh) 5 lb. | 1937 | 2 | 8.1 | 3 | 0.32 |
| | 1938 | 1 | 7.3 | 4 | 0.38 |
| Lime sulfur 2 gal.+wettable sulfur (325 mesh) 5 lb. | 1937 | 2 | 8.1 | 3 | 0.35 |
| | 1939 | 1 | 7.0 | 3 | 0.31 |
| Lime sulfur 1 gal.+wettable sulfur (325 mesh) 10 lb. | 1937 | 2 | 8.1 | 3 | 0.36 |
| Lime sulfur 2 gal.+wettable sulfur (4,000 mesh) 5 lb. | 1939 | 1 | 7.9 | 2 | 0.25 |
| Dry lime sulfur 5 lb. | 1937 | 2 | 8.1 | 3 | 0.36 |
| | 1938 | 1 | 6.6 | 5 | 0.49 |
| Dry lime sulfur 5 lb.+wettable sulfur (325 mesh) 5 lb. | 1937 | 2 | 8.1 | 3 | 0.40 |
| Dry lime sulfur 8 lb.+wettable sulfur (325 mesh) 5 lb. | 1937 | 2 | 8.1 | 3 | 0.47 |
| Wettable sulfur (325 mesh) 10 lb. | 1939 | 1 | 7.2 | 3 | 0.29 |
| Wettable sulfur (4,000 mesh) 10 lb. | 1938 | 2 | 5.8 | 4 | 0.37 |
| | 1939 | 1 | 7.6 | 3 | 0.36 |
| *Dusts* | | | *Pounds* | | |
| Sulfur (325 mesh) | 1938 | 2 | 0.74 | 6 | 0.12 |
| | 1939 | 1 | 1.00 | 4 | 0.10 |
| Sulfur (2,000 mesh) | 1939 | 1 | 0.50 | 4 | 0.11 |

* Quantities are per 100 gallons for spray mixtures.
† All the trees treated were in Valencia groves except in 1936, when Parson Brown groves were used.

used commercially for the control of rust mites. All materials were applied with the same power sprayer or power duster, and the equipment employed with each outfit was similar throughout all tests. The trees were treated thoroughly, and amounts of material were used adequate to give satisfactory rust-mite control. The data presented were taken from experiments conducted in 1936 on Parson Brown, an early variety, and on Valencia, a late variety, during subsequent years. The Parson Brown trees were eleven years old in 1936, and in 1937 the Valencia groves had been planted twelve years.

Spray and dust materials have been purchased in large enough quantities for the costs to be comparable with prices to growers in central Florida. The expense of making experimental applications, however, is higher than cost to growers. In deriving the cost estimates given above, after an investigation of grower and commercial expenses, a flat charge of 1 cent per gallon of material

was decided upon for making a spray application and ½ cent per tree for a dust application. The charge for a dust application was based on a tree unit rather than quantity of material applied, because large quantities of dust can be applied with very little more labor or time than small quantities, but the application of large amounts of spray material ordinarily requires more time and labor than the application of smaller amounts. These application costs cover labor and depreciation of spraying and dusting equipment and are used uniformly in the calculations to give a fair comparison of the materials used and the spray programs followed.

The costs of spray and dust materials and the estimated expenses of application are listed below:

| | |
|---|---|
| Lime sulfur (32° Be.) | $0.14 per gal. |
| Wettable sulfur, 325-mesh, 90% pure sulfur | .035 per lb. |
| Wettable sulfur, 4,000-mesh, 99.5% pure sulfur | .06 per lb. |
| Dry lime sulfur | .095 per lb. |
| Dusting sulfur, 325-mesh, 93% pure sulfur | .02 per lb. |
| Dusting sulfur, 2,000-mesh, 98.5% pure sulfur | .047 per lb. |
| Cost of spraying (labor and depreciation) | .01 per gal. |
| Cost of dusting (labor and depreciation) | .005 per tree |

The costs of the various spray and dust programs have been calculated from the prices of insecticides used, the estimated costs of application and depreciation of equipment as given above, the average amount of material applied to each tree per application, and the number of applications per crop. These data, based on a tree unit per crop, are given in table 1.

DISCUSSION.—All treatments recorded in table 1 were effective in controlling rust mites, but some materials adhered to fruit and foliage longer than others, thereby reducing the number of applications necessary. Variations in tree size, density of foliage, and the efficiency of operator were responsible for differences in the amounts of material applied per tree. Variations in infestation of rust mites in different groves during the same years and in the same grove in different years, and in the time of maturing of fruits were also responsible for differences in the number of applications of the same material.

In 1936, in the Parson Brown grove, two applications of lime sulfur plus wettable sulfur at a total cost of 21 cents per tree were less expensive than three applications of lime sulfur alone, which cost 25 cents. In the No. 1 valencia grove in 1937 five applications of lime sulfur and four applications of lime sulfur plus wettable sulfur each cost 53 cents, even though slightly more of the first spray was used in each application. The cheapest schedule in the No. 2 grove during 1937 was three applications of lime sulfur, 1 gallon, plus wettable sulfur, 5 pounds, at a cost of 32 cents. Three applications of lime sulfur, 2 gallons, plus wettable sulfur, 10 pounds, cost 33 cents although less spray was used in each application. Other treatments in this grove were more expensive, the greatest cost being 47 cents for three applications of dry lime sulfur, 8 pounds, plus wettable sulfur, 5 pounds.

In grove No. 1 in 1938, a schedule of four applications of lime sulfur alone at a total cost of 36 cents was cheaper than four applications of two lime sulfur and wettable sulfur combinations, or five applications of dry lime sulfur. In grove No. 2 during the same year, a program of six applications of 325-mesh dusting sulfur costing 12 cents per tree was much cheaper than the two least expensive spray treatments—five applications of lime sulfur alone which cost 38 cents and four sprays of 4,000-mesh wettable sulfur, 10 pounds, which cost 37 cents. Four sprays of lime sulfur, 2 gallons with wettable sulfur (325-mesh), 10 pounds, cost 44 cents. During 1939 in grove No. 1, 325-mesh and 2,000-mesh dusting sulfurs were the cheapest. The finer dust was slightly more expensive, although only half the quantity was needed in each of four applications to cover trees of similar size. Lime sulfur plus wettable sulfur at a cost of 25 cents was the cheapest spray mixture used during the season in this grove.

RETURNS FROM RUST MITE CONTROL.—Fruit yield records taken at harvest time during the course of the experimental work showed that controlling the rust mite increased the production of oranges on an average 0.63 box per tree. In 1936, 1937, and 1939, a large grower in central Florida received for early oranges, of which Parson Brown is a leading variety, averages of $1.91, $1.50, and $1.16 per

box, respectively, or an average of $1.49 for the three years. The increased production of 0.63 box per tree as the result of controlling rust mites, computed at $1.49 per box, results in an increased return of approximately $0.93 a tree, which would exceed by $0.68 per tree the cost of the more expensive rust mite control schedule for Parson Brown oranges given in table 1. In the same years Valencia oranges brought the same grower averages of $2.81, $1.16, and $1.54 per box, or a three-year average of $1.65 per box. The increased production of 0.63 box per tree, calculated at $1.65 per box, results in an increased return of approximately $1.03 per tree, which would exceed by $0.50 per tree the cost of the most expensive schedule given in table 1.

SUMMARY.—Costs of sulfur spray and dust treatments for the control of the citrus rust mite (*Phyllocoptes oleivorus* Ashm.) in Florida have been calculated from data collected over a period of four years from experimental plots in six orange groves.

In general, control of rust mites, and of russeting, by dusting with sulfur is very much cheaper than by spraying with any of the ordinary spray combinations, ranging from 10 to 12 cents per tree for dusted Valencia compared to 25 cents per tree for the cheapest spray program.

Addition of wettable sulfurs to lime sulfur reduced the number of applications required in a season, but during a heavy rust mite year on Valencia trees a schedule employing lime sulfur alone was cheaper, although an extra application was required. Generally, the addition of 5 pounds of wettable sulfur to lime sulfur solution gave as good protection as the addition of 10 pounds, and was cheaper.

Dry lime sulfur sprays were more costly than most of the other comparable spray treatments.

Experimental procedure with all the above treatments gave commercial control of rust mites and prevented russeting of fruit equally well.

Controlling rust mites increased fruit production, resulting in a profitable return, the increased return for Parson Brown oranges being 68 cents per tree and for Valencias 50 cents.—12-6-39.

# Vitamin Content of Bee Foods

## *II. Vitamin $B_1$ Content of Royal Jelly and Bee Bread*[1]

MYKOLA H. HAYDAK and LEROY S. PALMER, *University of Minnesota, St. Paul*

While a satisfactory amount of work has been done on the vitamin E content of royal jelly and pollen (Haydak and Pamer, 1938) the data on the presence of other vitamins in bee foods are meager. Dutcher (1918) found that "corn pollen is relatively rich in water-soluble vitamine" and Aeppler (1922) concluded that "larval food contains considerable quantities of water soluble B." Recently Melampy and Jones (1939) found that vitamin $B_1$ content of royal jelly is between 1 to 1½ International Units per gram. These are the only published attempts to determine the water-soluble vitamins in royal jelly and pollen.

METHOD.—In the study of vitamin $B_1$ content of bee foods, the authors followed the technic of the cure of convulsions in rats (Kline, Tolle and Nelson, 1938), but employed the following modified ration: purified casein 18, autoclaved yeast 8, Hawk and Oser (1931) salt mixture 4, *Crisco* 8, Cod liver oil 2, and dextrin 60. Rats four weeks old, weighing from 40 to 60 gms. were used in the experiment. When the time came for the symptoms to appear, the rats were excited by twirling them by their tails. Those which showed acute symptoms were given 1.5 gm. royal jelly or 1.5 gm. of bee bread or 5 micrograms of thiamin chloride, and the number of days during which they remained free of symptoms was ascertained. The same rat has been used for from one to seven trials. The animals weighed from 47 to 62 gms. when the curative dose was administered for the first time. Fourteen trials (9 rats) with royal jelly, 25 trials

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(10 rats) with bee bread and 24 trials (15 rats—the same rats which were used for royal jelly and bee bread study) with thiamin chloride were performed. The average curative period for royal jelly was 5.4 days; for bee bread, 8 days; and for thiamin chloride, 5.9 days.

**Table 1.—Tests of vitamin content of royal jelly and bee bread.**

| | Approximate Thiamin Chloride per Gram in Micrograms | | Approximate Units Vitamin $B_1$ per Gram | |
|---|---|---|---|---|
| | Fresh | Dry | Fresh | Dry |
| Royal jelly | 3.1 | 9.1 | 1.0 | 3.1 |
| Bee bread | 4.5 | 6.4 | 1.5 | 2.1 |

RESULTS.—It has been ascertained that "at medium levels the duration of cure is very nearly proportional to the weight of vitamin given" (Birch and Harris, 1934), therefore the potency of the tested substances can be easily determined.

The results obtained are summarized in the following table. The water content of the royal jelly was taken as 66 per cent (McCleskey & Melampy, 1939) and that of the bee bread was found to be 29 per cent. The calculations in terms of International Units were based on the definition that one unit of vitamin $B_1$ potency is exerted by 3γ of crystalline thiamin chloride.

CONCLUSIONS.—Royal jelly exhibits vitamin $B_1$ activity towards polyneuritic rats equal to about 3γ of thiamin chloride per gram of fresh and 9γ per gram of dry matter. Bee bread shows vitamin $B_1$ activity towards polyneuritic rats corresponding to that of 4.5γ and 6.4γ of thiamin chloride per gram of fresh and dry matter respectively.—12-27-39.

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# Comparative Value of Pollen and Pollen Substitutes

## *II. Bee Bread and Soy Bean Flour*[1]

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In a previous communication (Haydak, 1939) the results of an investigation on the comparative value of bee bread and cottonseed meal-dry skim milk mixture has been described. In the present experiment this comparison has been extended to include various brands of soy bean flour and the soy bean flour-dry skim milk mixture. The author has proven (Haydak, 1937) that bees can rear brood when given soy bean flour instead of pollen. Peterka and Svoboda (1938) showed that the pharyngeal glands of young bees develop normally if the bees are fed *Soyasan*, a brand of soy bean flour.

The method and the procedure of the present experiment did not differ from the one described previously (Haydak, 1939). However, after the comb with sealed brood had been removed from the colony, the bees were allowed to rear the

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second brood and the value of emerging bees so produced has also been ascertained.

FOODS.—Bee bread stored by bees during the summer of 1938 was used. A paste was prepared by mixing 35 gm. of bee bread with 10 cc. of water and 200 gm. of honey. Soy bean flour or soybean flour-dry skim milk (4:1 by weight) foods were prepared by mixing 35 gm. of dry food with 200 gm. of honey and adding 20 cc. of water to compensate the difference in moisture content of the bee bread and the flour.

Three brands of soy bean flour have been used in this experiment:

1. Soy bean flour procured from regular expeller processed soy bean oil meal with 5 per cent of fat (SBF-1).

2. Soy bean flour made by expeller process from disimbittered, dehulled and degerminated soy beans with 7.5 per cent of fat (SBF-2).

3. Soy bean flour from steamed, dehulled beans with 22 per cent of fat content (SBF-3).

RESULTS AND DISCUSSION.—The results of the experiment are presented in table 1. The changes in weights of thoraces indicate that there was no marked difference in the development of the bees in all colonies except that fed SBF-3 food. Although the protein content of this flour was 41 per cent, it is possible that the availability of proteins was poor since it has been found (Hayward, *et al.*, 1936) that the nutritive value of proteins of the raw soy beans or those processed under low temperature is about half that obtained from beans heated to 140–150° F. It might have happened that steaming the beans did not expose them to a sufficiently high temperature. A high mortality in this colony suggests some kind of disturbance of normal life processes in the bees. This colony did not rear brood, although several larvae were brought to the sealing stage and some of them even sealed, but these were removed by the bees two days later. The food supplied to the larvae was watery in consistency and very little of it could be noticed in the cells.

One of the colonies fed soy bean flour-dry skim milk mixture did not rear brood, although the next colony, fed the same food, reared more brood than the control, or pollen fed colony. The addition of lactic acid and amyl acetate did not stimulate the brood rearing (preliminary experiments indicated that the addition of lactic acid and an odorous substance help in starting brood rearing). High mortality in this colony should be noted. It is difficult to explain such a result in an otherwise normal colony.

One of the pollen fed colonies had not started brood rearing until 21 days after the queen was added to the colony while another colony, supplied with the same food, began normal brood rearing activities on the ninth day after the queen had been placed in the hive. Mortality in both colonies was low.

Mortality in the colonies fed pollen substitutes was in general higher than that of the control. However, only 11.9 per cent of the bees died in one of the

**Table 1.—Composite results of feeding bee bread, soy bean flour, and soy bean flour-dry skim milk mixture.**

| | DATA ON BEES USED IN THE EXPERIMENTAL COLONIES | | | | | | | DATA ON BEES REARED BY THE EXPERIMENTAL COLONIES | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Development (Weight of thoraces of bees in milligrams) | | | | | | (Weight of emerging bees in milligrams) | | | |
| Food | Number Bees per Colony | Emerging Bees | 2 Days Old | 4 Days Old | 6 Days Old | 8 Days Old | Mortality | 1st Brood | 2nd Brood | Number Reared | INDICES OF FOOD EFFICIENCY |
| Bee bread | | | | | | | | | | | |
| A | 3918 | 9.1 | 11.5 | 12.8 | 12.5 | 13.6 | 13.1[17] | 0 | 19.3 | 191 | 6.3 |
| B | 3899 | 9.1 | 11.6 | 12.4 | 12.8 | 13.1 | 16.7 | 16.4 | 16.1 | 490 | 8.6 |
| SBF-1 | | | | | | | | | | | |
| A | 4330 | 9.1 | 12.7 | 12.9 | 13.6 | 14.3 | 25.4 | 17.4 | 17.6 | 239 | 6.4 |
| B | 4245 | 9.1 | 11.9 | 13.0 | 14.3 | 14.2 | 15.4 | 16.2 | — | 201 | 5.9 |
| SBF-2 | 4996 | 9.1 | 10.9 | — | 12.7 | 13.4 | 24.2 | 15.5 | — | 145 | 4.6 |
| SBF-3 | 5596 | 9.1 | 10.9 | 11.9 | — | 11.8 | 35.7 | 0 | 0 | 0 | 2.0 |
| SBF-2 | | | | | | | | | | | |
| Dry skim milk | | | | | | | | | | | |
| A | 4843 | 9.1 | 11.3 | 12.5 | 12.8 | 13.6 | 31.1 | 0 | 0 | 0 | 2.2 |
| B | 4773 | 9.1 | 12.6 | — | 14.3 | 14.2 | 11.9 | 18.3 | 18.7 | 576 | 10.6 |

colonies fed SBF-2-dry skim milk mixture. The latter colony reared the largest number of bees.

The weights of the emerging bees produced by the experimental colonies varied considerably, but were quite consistent for the two broods in the same colony. It was impossible to establish the weights of the emerging bees from the second brood of SBF-1B and SBF-2 colonies because of destruction by the wax moth larvae.

Giving one point for the lowest performance in each colony (weight of 8-day old bees, mortality, weight of emerging bees, number of reared young) and determining the number of points correspondingly gained by other colonies which showed better results, a numerical relation of total results for each colony can be obtained. These indices are given in the last column of the table.

SUMMARY AND CONCLUSIONS.—Colonies consisting of young bees which have never eaten pollen were kept under controlled conditions and fed bee bread, various brands of soy bean flour, and soy bean flour-dry skim milk mixture respectively. The development of bodies of the bees in the experimental colonies proceeded normally, except in the colony which was fed the soy bean flour of high fat content and low temperature treatment, where the development was retarded. Mortality in the colonies fed pollen substitutes was, on an average, higher than that in the control colonies. The number of bees reared by the experimental colonies varied considerably, being lower in the colonies fed soy bean flour and higher than that in the control in the colony which was supplied with soy bean flour-dry skim milk mixture. The weights of emerging bees produced by the experimental colonies, on an average, compared favorably with those of the control.—12-27-39.

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# The Thermal Resistance of *Bacillus larvae*

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Since *Bacillus larvae* was first shown to be the cause of American foulbrood White (1907), beekeepers have shown interest in the use of heat for saving equipment, honey, and wax from diseased colonies. Each year the Bureau of Entomology and Plant Quarantine receives inquiries regarding destruction of *B. larvae* by heating. Some of these have come from beekeepers who boiled honey from diseased colonies and fed it to healthy ones or boiled equipment and used it again in their apiaries. Others are from beekeepers who used material from diseased colonies after treating it with steam. Reports on the success or failure of these experiments by beekeepers are largely unavailable or inconclusive.

White (1907), who was the first to study the effect of heat on *Bacillus larvae*, reported that spores were virulent after heating at 65 degrees C.[1] for 20 minutes. Later White (1914) reported that *B. larvae* spores were killed in less than 5 minutes at 100 degrees, but still later (1920) that spores in water were alive after 10 minutes at 100 degrees but not after 11 minutes while spores in honey resisted 107 degrees for 40 minutes. The heated spores were tested by culturing or by inoculating colonies of bees.

Results similar to those of White were obtained by Grandi (1934), who reported that *Bacillus larvae* spores did not resist 99 degrees more than 13 minutes in water or more than 15 minutes in honey or diluted honey. Grandi tested heated spores by inoculating medium containing egg yolk with 0.5 cubic centimeter of sus-

[1] All temperatures in Centigrade.

pension containing not less than a million spores and incubating the cultures for 30 days.

Borchert (1937) reported that *Bacillus larvae* resisted dry heat at 100 degrees for 8 hours without any killing effect, but when spores were in water a killing effect was observed after 115 to 120 minutes at 90 degrees and after 55 to 60 minutes at 95 degrees. Borchert does not explain how the heated spores were tested for viability.

Considerable work has been done on the thermal resistance of bacterial spores other than *Bacillus larvae*. A few of the results pertinent to this investigation are mentioned.

The common potato bacillus (*Bacillus mesentericus*) was shown by Globig (1888) to withstand streaming steam at 100 degrees for 5 to 6½ hours, superheated steam at 113–116 degrees for 25 minutes, 122–123 degrees for 10 minutes, 126 degrees for 3 minutes, and 127–128 degrees for 2 minutes.

The thermal resistance of spore bearers isolated from canned foods was found by Esty and Williams (1920) to vary from 1½ hours to 17 hours at 100 degrees.

Heating greatly increased the germination time of *Clostridium botulinum* in experiments of Dickson *et al.* (1925). Most of the cultures that germinated did so within 1 month, but dormancies up to 37 months were noted.

Working with *Bacillus subtilis*, *B. cohaerens*, *B. albolactis*, and an unidentified species, Curran and Evans (1937) found that spores which survive drastic killing influences are much more exacting in their nutritive requirements than the less resistant individuals, which comprise the bulk of the viable population before treatment. Addition of enrichment substances to the culture media was found essential for accurate enumeration of bacteria previously exposed to highly lethal factors. Spores that survived lethal factors lost vitality rapidly when seeded on inadequate media.

EXPERIMENTAL PROCEDURE.—The present investigation was made to provide a foundation for practical tests on the use of heat for saving apiary products and equipment from American foulbrood colonies. Spores were obtained from diseased combs sent to the laboratory from the chief beekeeping sections of the United States. Tests were usually made with a mixture of spores from several samples, but at times spores from only one comb at a time were used. The spore material was either weighed or counted to determine the approximate number of spores.

Scales were either macerated and the spores suspended or saturated by soaking before being heated in water. Dry scales were exposed either to dry heat or to steam at atmospheric or increased pressure. Dried and pulverized scales were also heated in beeswax. Heating was done by boiling, by exposure to steam, or by exposure to dry heat for suitable periods.

Cultures were usually prepared on agar slants with approximately 2,500,000,000 spores in 1 cubic centimeter of water, and incubation was continued for 30 days before negative results were recorded. The culture medium generally used was modified from formulas given by Sturtevant (1924) and Lochhead (1928) and enriched with egg yolk, carrot extract, dextrose, and freshly prepared yeast extract. Cultures were inspected at frequent intervals, and water was added weekly to replace loss from evaporation. When growth was detected, cultures were examined microscopically and tested for nitrite nitrogen. Since vegetating *Bacillus larvae* stores nitrite in the medium, a red color develops in positive cultures when sulfanilic acid and alpha-naphthylamine acetate are added. This test was thought to be specific for *B. larvae*, but the writer (1940) has recently isolated two other bacterial species which also store nitrite in the medium.

CULTURAL RESULTS.—The cultural results obtained with heated spores are shown in tables 1 to 7.

Table 1 shows cultural results with spores heated in water at atmospheric pressure. Temperatures below boiling were maintained in an electric oven. A boiling temperature (approximately 99.3 degrees) was maintained in a steam sterilizer or in a covered vessel over a flame. Growth was obtained from spores heated at 66 degrees for 19 days but not from those heated from 39 days or longer. All cultures with spores heated for 10 days at 70 degrees gave growth, although germination was delayed. Spores heated for 13 days at 75 degrees gave growth in

culture, but those heated for 18 days or longer did not. Sterilization was incomplete after 4½ hours at 98 degrees, but spores heated at this temperature for 10 hours did not grow. After being heated for 7 hours at 99.3 degrees, spores were still viable although the percentage of positive cultures was small. All cultures with spores heated for 8 and 10 hours remained negative when tested for growth.

**Table 1.—Vegetative growth in cultures of *Bacillus larvae* from spores heated in water at atmospheric pressure.**

| TEMPERATURE, DEGREES | PERIOD OF HEATING | NUMBER OF CULTURES | CULTURES GIVING GROWTH |
|---|---|---|---|
| 66 | 4½ hours | 5 | 100% |
| | 21 hours | 5 | 100 |
| | 48 hours | 5 | 100 |
| | 3 days | 5 | 100 |
| | 5 days | 5 | 100 |
| | 9 days | 5 | 100 |
| | 17 days | 10 | 70 |
| | 19 days | 10 | 20 |
| | 39 days | 10 | 0 |
| | 45 days | 7 | 0 |
| | 52 days | 6 | 0 |
| | 83 days | 25 | 0 |
| | 105 days | 8 | 0 |
| 70 | 4 hours | 3 | 100% |
| | 1 day | 4 | 100 |
| | 2 days | 5 | 100 |
| | 6 days | 3 | 100 |
| | 8 days | 8 | 100 |
| | 10 days | 4 | 100 |
| 75 | 7 days | 10 | 0% |
| | 10 days | 10 | 0 |
| | 13 days | 10 | 70 |
| | 18 days | 5 | 0 |
| | 20 days | 8 | 0 |
| | 30 days | 5 | 0 |
| 98 | 1 hour | 10 | 10.00% |
| | 2 hours | 7 | 71.43 |
| | 4½ hours | 10 | 10 |
| | 10 hours | 10 | 0 |
| | 21 hours | 7 | 0 |
| | 29 hours | 6 | 0 |
| 99.3 | ½ hour | 152 | 15.13% |
| | 1 hour | 126 | 42.06 |
| | 2 hours | 233 | 31.33 |
| | 3 hours | 145 | 26.21 |
| | 5 hours | 150 | 7.33 |
| | 6 hours | 104 | 2.88 |
| | 7 hours | 41 | 4.88 |
| | 8 hours | 47 | 0 |
| | 10 hours | 48 | 0 |

Table 2 shows results with spores heated by exposing American foulbrood scales to flowing steam. Scales in the 4-, 5-, and 6-hour tests were heated in open 500 cubic centimeter flasks. All others were heated in open Petri dishes. Scales in Petri dishes appeared saturated after about 30 minutes' heating, but those in flasks did not absorb enough water to saturate them. This probably accounts for the higher percentage of positive cultures when scales were exposed in flasks. Incubation test of spores heated 5 hours was terminated after 8 days owing to accidental contamination of most of the cultures. Out of 63 such cultures, however, 6 were positive before contamination occurred. Sterilization was still incomplete after 7 hours' heating, but spores heated for 8 hours did not grow after the treatment.

**Table 2.—Vegetative growth in cultures of *Bacillus larvae* from spores in American foulbrood scales heated at 99.3°C. by flowing steam at atmospheric pressure.**

| PERIOD OF HEATING, HOURS | NUMBER OF CULTURES | CULTURES GIVING GROWTH |
|---|---|---|
| ½ | 15 | 40.00% |
| 1 | 44 | 18.18 |
| 2 | 56 | 10.71 |
| 2½ | 49 | 65.30 |
| 3 | 33 | 15.15 |
| 4 | 52 | 50 |
| 5 | 63 | —* |
| 6 | 39 | 51.28 |
| 7 | 117 | 6.83 |
| 8 | 80 | 0 |
| 10 | 63 | 0 |

* Test incomplete owing to accidental contamination, but 9.53 per cent of the cultures were positive before contamination occurred.

Cultures shown in table 3 were prepared with spores boiled in honey diluted with an equal volume of water, recovered by centrifuging and washed before cultured. The boiling temperature of the diluted honey ranged from about 103 degrees for the shorter periods to 105 or 106 degrees after 5 hours. Growth was

**Table 3.—Vegetative growth in cultures of *Bacillus larvae* from spores boiled in 50 per cent honey-water solution.**

| AVERAGE TEMPERATURE | PERIOD OF HEATING, HOURS | NUMBER OF CULTURES | CULTURES GIVING GROWTH |
|---|---|---|---|
| 103 | ½ | 31 | 67.74% |
| 103 | 1 | 37 | 40.54 |
| 104 | 2 | 49 | 22.50 |
| 104 | 3 | 49 | 4.08 |
| 105 | 4 | 73 | 13.69 |
| 106 | 5 | 55 | 7.27 |

obtained from spores boiled for each of the periods tested.

Table 4 shows the results of autoclaving spores at 15 pounds, when heated dry and in water. Some of the scales heated with water were first macerated and the spores suspended, while others were only saturated. No difference was detected owing to the use of these two modifications. Growth was obtained from wet spores autoclaved for 25 minutes, but all cultures with wet spores autoclaved for 30 minutes remained negative. The dry scales were still viable after autoclaving for 40 minutes.

**Table 4.—Vegetative growth in cultures of *Bacillus larvae* from scales heated in an autoclave at 15 pounds' pressure.**

| Period of Heating, Minutes | Number of Cultures | Cultures Giving Growth |
|---|---|---|
| Scales heated in water | | |
| 20 | 44 | 52.27% |
| 25 | 54 | 16.33 |
| 30 | 50 | 0 |
| Scales heated dry | | |
| 5 | 19 | 78.94 |
| 10 | 11 | 54.54 |
| 15 | 12 | 33.33 |
| 20 | 34 | 11.76 |
| 25 | 16 | 81.75 |
| 30 | 25 | 8.00 |
| 40 | 102 | 3.92 |
| 50 | 52 | 0 |

Table 5 gives the results of culturing spores heated in water suspension at 99.3 degrees with amount of inoculum varied by diluting fractions of the heated suspension with water. Each culture was inoculated with 1 cubic centimeter of inoculum adjusted to contain approximately the desired number of spores. The percentage of positive cultures decreased as the number of spores added to the culture tubes was decreased. Growth was obtained in all cases where heating was limited to 5 minutes. Inoculation with 2,500,000,000 and 500,000,000 spores heated for 15 minutes gave growth, but only 40 per cent of the cultures with 100,000,000 and 10 per cent with 20,000,000 were positive after the same amount of heating. After heating for 30 minutes and for 1 hour cultures with the two heavier inoculums also gave growth, but all cultures with the two lighter inoculums remained negative. These results indicate

**Table 5.—Vegetative growth in cultures of *Bacillus larvae* from spores heated in water at 99.3 degrees C. when the amount of inoculum was varied.**

| Period of Heating, Minutes | Approximate Number of Spores per Culture, Millions | Total Number of Cultures | Cultures Giving Growth |
|---|---|---|---|
| 5 | 2,500 | 7 | 100.00% |
| | 500 | 9 | 100 |
| | 100 | 10 | 100 |
| | 20 | 10 | 100 |
| 15 | 2,500 | 10 | 100.00% |
| | 500 | 10 | 100 |
| | 100 | 10 | 40 |
| | 20 | 10 | 10 |
| 30 | 2,500 | 10 | 100.00% |
| | 500 | 15 | 26.66 |
| | 100 | 12 | 0 |
| | 20 | 12 | 0 |
| 60 | 2,500 | 10 | 10.00% |
| | 500 | 10 | 10 |
| | 100 | 10 | 0 |
| | 20 | 10 | 0 |

the importance of heavy inoculums for accurate determination of the thermal resistance of *Bacillus larvae* in controlled tests.

Table 6 shows how dry heat affects the

**Table 6.—Vegetative growth in cultures of *Bacillus larvae* from American foulbrood scales exposed to dry heat.**

| Temperature, Degrees | Period of Heating | Number of Cultures | Cultures Giving Growth |
|---|---|---|---|
| 66 | 1 days | 5 | 100.00% |
| | 2 | 5 | 100 |
| | 3 | 5 | 100 |
| | 6 | 5 | 100 |
| | 19 | 6 | 100 |
| | 39 | 9 | 100 |
| | 45 | 5 | 100 |
| | 52 | 9 | 55.55 |
| | 168 | 15 | 0 |
| 75 | 5 days | 10 | 100 |
| | 7 | 10 | 100 |
| | 10 | 10 | 100 |
| | 13 | 10 | 30 |
| | 18 | 10 | 0 |
| | 20 | 8 | 0 |
| | 30 | 10 | 0 |
| | 52 | 8 | 0 |
| | 73 | 14 | 0 |
| 98 | 21 hours | 20 | 10 |
| | 46 hours | 9 | 22.22 |
| | 93 hours | 10 | 0 |
| | 6 days | 6 | 0 |

viability of *Bacillus larvae* when scales are exposed in open Petri dishes. At 66 degrees spores were affected but little; even after 52 days' exposure 55 per cent of the cultures grew. After exposure for 168 days none of the cultures grew. After prolonged incubation 30 per cent of cultures with spores exposed 13 days at 75 degrees gave growth, but after 18 days' exposure all cultures remained negative. After 46 hours' exposure at 98 degrees 22 per cent of the cultures grew, but after exposure for 93 hours none showed growth.

**Table 7.—Vegetative growth in cultures of *Bacillus larvae* from spores heated in beeswax.**

| TEMPERATURE, DEGREES | PERIOD OF HEATING | NUMBER OF CULTURES | CULTURES GIVING GROWTH |
|---|---|---|---|
| 66 | 4½ hours | 5 | 100.00% |
| | 21 hours | 5 | 100 |
| | 2 days | 5 | 100 |
| | 3 days | 5 | 100 |
| | 8 days | 5 | 100 |
| | 19 days | 10 | 100 |
| | 39 days | 8 | 100 |
| | 52 days | 7 | 100 |
| | 83 days | 10 | 100 |
| 75 | 5 days | 10 | 100.00% |
| | 7 days | 15 | 100 |
| | 10 days | 11 | 100 |
| | 13 days | 10 | 100 |
| | 18 days | 6 | 0 |
| | 20 days | 8 | 84.35 |
| | 30 days | 5 | 60 |
| | 42 days | 15 | 6.6 |
| | 52 days | 12 | 0 |
| 98 | 4½ hours | 7 | 100.00% |
| | 21 hours | 10 | 20 |
| | 29 hours | 9 | 0 |
| | 46 hours | 9 | 0 |
| | 93 hours | 10 | 0 |
| | 7 days | 8 | 0 |
| 100 | 19 hours | 10 | 100.00% |
| | 24 hours | 10 | 100 |
| | 43 hours | 10 | 100 |
| | 47 hours | 10 | 100 |
| | 91 hours | 10 | 100 |
| | 119 hours | 5 | 60 |

Table 7 indicates that beeswax gives some protection to *Bacillus larvae* spores from damage by heat. Spores exposed in wax at 66 degrees for 83 days grew in all the cultures. Spores exposed at 75 degrees for 42 days gave growth in 6.6 per cent of the cultures, but none grew after exposure for 52 days. After exposure for 21 hours at 98 degrees, 20 per cent of the cultures were positive, but after 29 hours and longer all cultures remained negative. On the other hand, spores heated in wax at 100 degrees for 119 hours gave growth in 60 per cent of the cultures.

EFFECT OF HEATING ON VIRULENCE.—In 1937 tests on the viability of heated spores were supplemented by inoculation tests with colonies of bees. In July, 24 colonies were inoculated with approximately 500,000,000,000 spores per colony in 1 liter of sirup or diluted honey. Colonies were paired off, one pair receiving spores heated in diluted honey while the other received spores heated in water, four colonies being used for each of the following periods of heating: ½, 1, 2, 3, 4, and 5 hours. Each lot was tested in culture, and growth was obtained in all cases except that of the spores boiled in water for one-half hour. In this case it is apparent that the culture medium was not properly adjusted. The inoculated colonies were inspected periodically in 1937, 1938, and 1939, during which years all colonies remained free of American foulbrood.

During 1939 each of 16 colonies was inoculated with approximately 500,000,000,000 spores boiled in equal parts of honey and water. The spores given to 8 of the colonies were boiled for 15 minutes, to 4 colonies for 30 minutes, and to 4 others for 35 minutes. All colonies were inspected at weekly intervals until the close of brood rearing in November. All colonies remained free of disease.

DISCUSSION.—This investigation presents a different picture of the thermal resistance of *Bacillus larvae* spores from that obtained by earlier investigators, who invariably reported high susceptibility to heat. In some instances, for example, spores remained viable after having been heated more than twenty times as long as was formerly supposed sufficient to destroy them. These results, however, are in harmony with those of other investigators working with thermophilic bacteria other than *B. larvae*.

Under favorable cultural conditions untreated spores of *Bacillus larvae* germinate and multiply rapidly within 24 hours, giving fairly luxuriant growth after 48 hours. The first noticeable effect of heating is slight delay in germination and decreased luxuriance of growth. As the amount of heating is increased the luxuriance of growth decreases. After sufficient heating some cultures fail to grow while

others may germinate at any time after 3 or 4 days' incubation. Usually those cultures that germinate first give the most luxuriant growth. As sterilization approaches completion, most of the cultures fail to grow, whereas the lag period for those that do grow is usually long. When all cultures in any series remained negative for 30 days, sterilization was considered complete. In view of the work of Dickson *et al.* (1925) and others, it is possible that if cultures that failed to grow within 30 days had been incubated for a longer period growth might have resulted in some cases.

A common characteristic of all cultures with heat-treated spores of *Bacillus larvae* is a gradual decrease in the percentage that germinate as the amount of heat is increased. In cultures that grow after prolonged incubation, the great majority of spores do not germinate. In many instances growth appears to be initiated by relatively few spores; in fact, some cultures produce only one or a few isolated colonies. Viability of a large percentage of spores appears to be destroyed by relatively little heating. Some spores, however, seem to possess more than average resistance and are destroyed in proportion to their degree of resistance as heating is prolonged. A few spores seem to be highly resistant, and the extreme survivals observed in some cases can probably be explained by the presence of such spores.

It is not uncommon in bacteriological work to find heterogeneity in spores with respect to both resistance to heat and time of germination. Extreme variation in resistance to heat appears even in the spores from the same American foulbrood scale.

Morrison & Rettger (1930) have advanced the theory that what appears to be extreme variability in resistance to heat is due to the lack of specific favorable conditions in the culture medium rather than to inherent qualities of variability. If this were true, then there would necessarily be equally extreme variability in nutritive requirements among different spores of *Bacillus larvae* after exposure to extreme heating. If all spores were affected to the same degree by heat, it would seem that, when the media and cultural conditions are identical, there should be considerable uniformity in germination and growth of spores, but such was found not to be the case in the tests reported here.

To some extent these results seem to be in accord with those of Curran & Evans (1937), in that spores which survived drastic heating were more exacting in their nutritive requirements than was the bulk of the viable population before being heated.

The enriched medium used in this investigation was decidedly more favorable for growth of heated spores of *Bacillus larvae* than several others that have been employed for culturing this organism. When the latter media were used, spores heated for much shorter periods than have been found sufficient to destroy all of them usually failed to grow even with heavy inoculations and prolonged incubation. It seems probable that earlier investigators may have used less favorable media, and since much lighter inoculums were used than in the present work, these differences may explain the difference in results.

Results obtained thus far in colony-inoculation tests on the virulence of heated spores are more nearly in harmony with those of earlier investigators. Spores that survive 30 minutes' boiling, or possibly 15 minutes', either have too low a degree of virulence or are too few in numbers to be readily infectious when fed to colonies of bees.

If it were necessary to kill all *Bacillus larvae* spores by heating to prevent infection, the use of heat for saving equipment or products from diseased colonies could scarcely be made practical. The fact that virulence appears to be rather quickly destroyed when compared with viability seems to leave room, should conditions warrant, for the practical use of heat for saving equipment, honey, or wax from American foulbrood colonies.

SUMMARY.—Spores of *Bacillus larvae* were heated and their viability tested by culturing while their virulence was tested by inoculating colonies of bees.

Growth in culture was obtained from spores boiled in water or exposed to flowing steam for 7 hours, boiled in diluted honey for 5 hours, autoclaved at 15 pounds for 25 or 40 minutes, exposed to dry heat at 98 degrees for 2 days, and exposed in beeswax at 100 degrees for 5 days.

Spores boiled for 30 minutes and fed to

colonies had not produced disease after 3 years, while spores boiled for 15 minutes had not produced disease at the end of one season.

A favorable medium, heavy inoculations, and prolonged incubation were found necessary to produce growth of spores subjected to severe heating.

Extreme variation in cultural results with heated spores is thought to be due to variation in thermal resistance of individual spores.—1-6-40.

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# The Nitrite Nitrogen Test for *Bacillus larvae*

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In studies on *Bacillus larvae*, the cause of American foulbrood of bees, Lochhead (1927) found that nitrite is produced in peptone-carrot media to which no nitrates are added, marked evidence of nitrites being obtained after 24 hours' incubation at 37 degrees C.[1] in such media. Since ordinary nitrate-reducing species, "such as *B. cereus* or *Es. coli*," which are able to form nitrites in nitrate media, were unable to produce nitrites in recognizable amounts in peptone-carrot media, Lochhead thinks his results indicate that *B. larvae* produces nitrites by a process of oxidation in addition to being capable of forming nitrites by reduction of nitrates.

In further cultural studies on *Bacillus larvae*, Lochhead (1928) reports as follows concerning nitrite reduction by this organism: "In nitrate broth containing carrot extract a marked nitrite test is obtained due to growth of *B. larvae*. It is worthy of note, however, that nitrites can be readily detected in yeast-carrot broth or agar cultures without further addition of nitrate, under conditions where all nitrate-reducing bacteria so far tested have failed to give a nitrite reaction. There is evidence that this peculiar property may become of diagnostic value in the detection of *B. larvae*."

Sturtevant (1932) tested nitrite production in *Bacillus larvae* and in a series of miscellaneous organisms in standard nitrate broth, carrot extract broth, and carrot-extract agar. Most of the miscellaneous organisms gave positive nitrite tests within a few hours in all these media, but in carrot extract medium, in contrast to results with standard nitrate medium, the nitrite had apparently disappeared after 24 hours' incubation in most cases, and in all cases after 48 hours. *B. larvae* also gave positive nitrite tests in all the

[1] All temperatures are in Centigrade.

media, and tests in carrot-extract medium were still positive in cultures incubated for 5 days, as well as in cultures that had stood at room temperature 16 days after incubation for 4 days. Sturtevant (1932) states that it appears probable that in case of many contaminating organisms having the power to reduce nitrites that might get into cultures of *B. larvae* on carrot-extract medium, the nitrite, if produced by the contaminating organisms, would have disappeared after 48 hours' incubation.

Concerning the nitrite test with positive cultures of *Bacillus larvae* Sturtevant (1932) says, "... it was found that vegetative germination of spores of *Bacillus larvae* almost too slight to be seen would give a definite pink color on the addition of the reagents."

In studies on the effect of heat and other lethal agents on the viability of *Bacillus larvae* the present writer used a medium containing carrot extract in addition to extract of dry yeast, neopeptone, dextrose, buffer, and unheated egg yolk. Nutrient agar slants were inoculated with treated spores and incubated at 37 degrees for 30 days and in some cases for 60 days unless growth occurred after a shorter period of incubation. A protracted period of incubation was used, since *B. larvae* often shows a greatly increased lag period in culture after sublethal exposure to lethal agents. Cultures were examined for growth at intervals of from 3 to 5 days. Sterile water was added to the cultures at weekly intervals to replace loss from evaporation. All the cultures were tested for nitrite-nitrogen, after the maximum period of incubation or sooner when examination of the cultures showed that growth had occurred. The testing solutions were prepared according to directions given in Standard Methods for the Examination of Water and Sewage (1933). The test was made by adding 1 cubic centimeter of each of the two testing solutions to the culture tubes, or else by placing 2 or 3 drops of each solution on a small piece of agar cut from the slants with a sterile instrument and placed on a microscope slide. The latter procedure permitted further growth of the cultures whereas growth was prevented when the testing solutions were added to the tubes.

Pure cultures of *Bacillus larvae* always gave a positive nitrite test, indicated by a red coloration that appeared promptly in the testing solutions and gradually spread through the medium. The intensity of the color varied with the amount of growth. The color produced in vigorous cultures, when viewed by transmitted light in a column of the testing solution about 1½ inches deep, corresponded more closely to the rose red of Ridgway's color standards (1912) than to any other color shown. The suggestion was made that the color be designated as "watermelon red," to which it corresponds closely. The color produced in cultures with slight growth is less intense. The color gradually darkens when the tested cultures are allowed to stand at room temperature or the higher incubator temperature.

The suggestion was made by J. I. Hambleton that other organisms probably exist which store nitrite and that these may occasionally be contaminants in cultures of *Bacillus larvae*, as a result of which there is a positive nitrite test when the latter species has not grown. Opportunity was afforded, during the 4 years that this investigation has been in progress, for applying the nitrite-nitrogen test to a variety of contaminants.

STUDIES OF CONTAMINATED CULTURES.—Application of the nitrite test to contaminated cultures resulted in observations that seem to be of significance. For instance, on several occasions cultures in which growth of *Bacillus larvae* was identified both by microscopical examination and by a positive nitrite test with a portion of the agar, became contaminated after the examination was made. When the nitrite test was again applied to these cultures the reaction was negative. One of the contaminating organisms, a large spore-bearing rod, was plated and isolated in pure culture. When cultured in pure culture on medium containing carrot extract only negative nitrite tests were obtained. When inoculated into 2-day-old cultures of *B. larvae* which contained abundant vegetative rods and gave a strong positive nitrite test, this bacterium grew over the growth of *B. larvae* and covered most of the slanted surface. After 3 days' incubation these cultures were again tested for nitrite and only a negative reaction was obtained. It appears probable that nitrite stored by *B.*

*larvae* was destroyed by the other organism. When *Bacillus alvei*, *Bacillus para alvei*, and *Bacillus orpheus* were similarly introduced into cultures of *B. larvae*, luxuriant growth of all three species developed but the nitrite was not destroyed after incubation for 7 days. None of these bacteria stored nitrite in detectable amounts when cultured on medium containing carrot extract. Other morphological bacterial forms cultured from larvae sick or dead of European foulbrood reacted negatively to the nitrite test on medium containing carrot extract.

Three or four apparently different organisms have been encountered, however, which appear to store nitrite in medium containing carrot extract in a manner similar to storage of nitrite by *Bacillus larvae*. A pronounced positive nitrite test has been obtained in contaminated cultures when vegetative rods of *B. larvae* could not be detected by microscopical examination. Four contaminated cultures in which the only vegetative cells detected were of coccoid shape, appearing principally singly and in pairs, gave strongly positive nitrite tests. The contaminants had been growing for from 3 to 5 days before tests were made, but no further observations on the nitrite storing property of the organism were made, since attempts to subculture the contaminants, which appeared to be the same organism in each case, were unsuccessful, probably because the vegetative cells were killed by the testing solutions.

In 1938 a pronounced positive nitrite test was obtained with a culture in which a contaminant had formed a soft layer containing numerous spores. The gross appearance of the culture and morphology of the spores and sporangia were distinct from those of *Bacillus larvae*, but rods remained which resembled rods of the latter species. Poured-plate dilution cultures were prepared with basic agar for *B. larvae* but without egg yolk. Some of the plates were incubated at room temperature and others in an incubator at 37 degrees. Numerous colonies developed at both temperatures but growth was more rapid at 37 degrees. Cultures on agar slants were prepared from isolated colonies, and after spores had formed the organism was plated a second time and cultures again prepared from isolated colonies. The organism having been isolated in pure culture, its nitrite-storing properties were studied.

Cultures on agar prepared with carrot extract, with or without egg yolk, adjusted to approximately pH 7.0 gave a strongly positive nitrite test after 24 hours' incubation at 37 degrees. Cultures kept at room temperature grew more slowly and the color reaction after 24 hours was less pronounced. After 48 hours incubation a deeper red coloration developed when the testing solutions were added than after 24 hours' incubation. The depth of color produced when the testing solutions were added reached a maximum after 2 or 3 days' incubation and then seemed to remain about constant. Tests were made at daily intervals up to 14 days and then after weekly intervals up to 6 weeks. Pronounced positive nitrite tests were obtained in every instance, even with cultures in which the agar had dried to less than a quarter of its original volume. The color produced when testing solutions were added was indistinguishable from the color in cultures of *Bacillus larvae*. It can be concluded, therefore, that the bacterium concerned stores nitrite in the medium used, one containing carrot extract, and consequently cultures on this medium gave a positive nitrite-nitrogen test indistinguishable from that of *B. larvae*.

Early in 1939 a strongly positive nitrite test was obtained in another contaminated culture that had been inoculated with spores of *Bacillus larvae* heated in water at the boiling point for 6 hours. The contaminant had formed a somewhat tough layer, with numerous spores over most of the slanted surface when the test was applied. Both the gross characters of the culture and the morphology of the spores were different from those of *B. larvae* as well as from those of the nitrite-producing organism discussed above. Some of the vegetative cells, however, resembled closely those of *B. larvae*.

Subcultures on the same medium prepared with carrot extract and egg yolk gave growth, both at 37 degrees and at room temperature. After spores had formed, dilution agar plate cultures were prepared on agar containing neopeptone, dextrose, and buffer, a medium on which *Bacillus larvae* does not grow. Plates were

incubated both at 37 degrees C. and at room temperature. Development of colonies was more rapid at 37 degrees C., but numerous isolated colonies had developed after 48 hours at room temperature. Cultures on agar slants were prepared from isolated colonies that had developed at room temperature. After spores had formed the organism was plated a second time on medium unsuitable for growth of *B. larvae* and pure cultures prepared from isolated colonies that had developed at room temperature. When inoculations were made with a needle touched to an isolated colony containing only vegetative cells, egg yolk in the medium seemed to retard or prevent growth. The same procedure gave prompt growth on agar slants without egg, and transfers from these cultures to slants containing egg also grew promptly and luxuriantly.

POSITIVE NITRITE REACTION FROM A CONTAMINANT.—Pure cultures gave positive nitrite tests after 24 hours' incubation in medium containing carrot extract adjusted to pH 7.0, either with or without egg yolk. The intensity of the test seemed to increase during 2 or 3 days incubation and then remained constant at least for several weeks. Cultures were tested for nitrite after different periods of incubation up to 6 weeks, with positive results in every test. The color reaction with this organism was likewise indistinguishable from the reaction with *Bacillus larvae*.

In another series of cultures inoculated in 1939 with spores of *Bacillus larvae* that had been heated in water at 99.3 degrees for 6 hours and incubated for 60 days, three tubes on which growth was not detected with the naked eye gave strongly positive tests for nitrite. No vegetative cells that bore any resemblance to rods of *B. larvae* could be found in stained mounts, but cells of varied and irregular shapes that appeared to have grown in the cultures were common in each of the three tubes. Most of the cells were from 0.8$\mu$ to 1.5$\mu$ thick and from 1.5$\mu$ to 3.0$\mu$ long. Some cells were nearly spherical, while others were elongated with rounded ends. Some were noticeably thickened at one end and others thickened near the middle. Occasional extremes were seen which exceeded the dimensions given. Division seemed to be by fission and the cells of bacterial nature, but in some cells division resembled a pinching-off process while in others it resembled budding. The general appearance of the cells resembled degenerative or involution forms, and it was not determined to which of the morphological groups of bacteria they belonged. Subcultures failed to grow, indicating that the cells had been destroyed by the testing solutions.

An additional organism that appears to store nitrite in medium containing carrot extract was recently encountered in unpublished work by E. C. Holst, of the Bee Culture Laboratory, Bureau of Entomology and Plant Quarantine, at Laramie, Wyo.

SUMMARY.—Observations were made which show that *Bacillus larvae* is not the only bacterial species that stores nitrite in medium containing carrot extract, but without added nitrate. Two spore bearers with gross cultural and morphological characters distinct from those of *B. larvae* and from each other which store nitrite in the medium used for *B. larvae*, were isolated and grown in pure culture. Both organisms gave positive nitrite tests indistinguishable from this test with cultures of *B. larvae*, and the nitrite remained stored in the medium for at least 6 weeks. Positive nitrite tests were also obtained with several other contaminated cultures, when vegetative cells of *B. larvae* were not detected by microscopical examination. While the nitrite test is convenient and a useful presumptive test for detecting slight growth of *B. larvae*, it is evident that the gross appearance of any growth as well as the morphology of the organism must be considered before the conclusion is reached that growth of *B. larvae* has occurred.—1-6-40.

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# Nectar Secretion in Poinsettia Blossoms[1]

GEO. H. VANSELL, *United States Department of Agriculture, Bureau of Entomology and Plant Quarantine*

A survey of western honey plants has revealed a wide range in the sugar concentration of their nectars (2 to 70 per cent). In spite of the fact that honey production is based especially on nectar secretion in plants, little attention has been given to the factors governing this phenomenon in our country except by a few investigators such as Cook (1923), Kenoyer (1916), and Park (1930). Numerous reports of investigations in Europe have appeared, however. Bonnier's "Les Nectaires" (1878) is an outstanding discussion of nectary structure and secretion, and more recently Beutler (1930) in Germany has recorded numerous facts on the sugar in various nectaries as affected by rain and other factors.

**Table 1.—Sugar concentration of the nectar in four poinsettia plants under similar environmental conditions.**

| Plant No. | Sugar Concentration, Per Cent | | | | |
|---|---|---|---|---|---|
| | Nov. 30 | Dec. 1 | Dec. 2 | Dec. 3 | Average |
| 5 | 54.0 | 56.2 | 57.3 | 47.0 | 53.4 |
| 8 | 46.0 | 47.6 | 46.8 | 39.7 | 45.0 |
| 7 | 43.3 | 47.0 | 45.2 | 37.6 | 43.8 |
| 6 | 40.3 | 45.2 | 43.6 | 38.5 | 41.9 |

Although reference to the use of poinsettia plants in nectar studies was not found, they were known to have large nectaries which at times secreted a liberal quantity, and so appeared to be favorable plants for a laboratory study of nectar secretion. As a preliminary attempt to determine some of the factors involved in their secretion of nectar, 48 of these plants were observed in a greenhouse at Davis, Calif., throughout their blossoming period. Some were subjected to a number of different conditions for noting the changes in the quantity or quality of the nectars, while others remained continuously under optimum conditions, serving as check plants.

The plants were ordinary commercial cuttings as prepared for the Christmas market. There was a distinct variation in the shades of color in the showy leaves surrounding the blossoms, but otherwise the plants appeared to be uniform.

The nectar was collected by means of finely drawn glass pipettes. For refractometer examination the fluid was transferred directly to the instrument chamber, but for chemical analyses it was placed in stoppered vials with a layer of preserving toluene.

Poinsettia nectar was found to be colorless. Plants growing side by side showed an unexplained difference in the quantity and richness of nectar secreted. An example of the variation in concentration of four plants appears in table 1. Each plant occupied the same relative position as to sugar concentration day after day.

The plants required warmth for the secretion of nectar. When they were removed from the warm room to the cool room of the greenhouse (unheated except by the sun), the secretion was reduced to less than half, and upon removal to the colder bee house it stopped entirely after 24 hours. The thermostat in the warm room was set for 65 degrees F., but there was some fluctuation between temperatures during the night and the sunny part of the day (60 to 75 degrees). The temperature in the colder greenhouse ranged from about 48 to 63 degrees. In the bee house it approached 43 degrees at night and seldom exceeded 55 degrees during the day. All the plants began to secrete again after replacement in the warm room. Secretion was continuous in those plants that remained in the warm room throughout the tests.

Sunlight was conducive to maximum secretion. Plants covered by double hoods of black sateen cloth ceased secreting nectar at the end of the second or third day, while one thickness of cloth resulted in only lowered quantity even after 6-day exposures. Also during prolonged cloudy periods a reduced amount of nectar was produced by the check plants. For example, the average daily secretion near the end of a foggy period was 8.6 milligrams as compared with 23.3 milligrams during the clear period following. Subsequent exposure to sunlight revived secretion in all these cases.

[1] A contribution from the Bureau of Entomology and Plant Quarantine, United States Department of Agriculture, in cooperation with the University of California.

The sugar concentration of nectar after secretion is profoundly affected by the degree of saturation of the atmosphere. In the tight glass box where the atmosphere was saturated the nectar was greatly diluted. After removal from the box the diluted nectar became as concentrated as the average for those plants that were continuously unboxed. Data given in table 2 indicate that the concentration is in inverse proportion to the relative humidity.

**Table 2.—Effect of relative humidity on the sugar concentration of poinsettia nectar.**

| Location of Plant during Previous 24-Hour Period | Temperature Degrees F. | Relative Humidity, Per Cent | Sugar Concentration, Per Cent |
|---|---|---|---|
| Under glass box in warm room | 70 | Near 100 | 12.8 |
| Fully exposed in cold room | 48 | Approximately 80–85 | 28.5 |
| Fully exposed in warm room | 70 | 70 | 61.6 |

Pressures above atmospheric apparently increased the quantity of nectar. Several sets of plants were placed in air-tight glass compartments and exposed concurrently to increased or reduced pressure. All compartments contained wet planers' shavings to provide sufficient moisture to cause continuous sweating of the glass walls. The plants under high pressure showed such a decided increase in secretion that the nectar cups filled to overflowing within 24 hours. Secretion under reduced pressure was less than at normal air pressure. (Davis, Calif., is 57 feet above sea level.)

Soil moisture, or at least the continuance or cessation of the normal watering practice, affected the quantity of nectar secreted. When water was withheld, the reduction was very marked, but secretion did not entirely cease even under drought severe enough to cause wilting and subsequent dropping of all the green leaves. Plants dried out only moderately, and the quantity of nectar secreted became practically normal after they were again watered regularly.

Two sets of data, from separate laboratories of the University of California, on the amounts of the various sugars present in the nectar were not in agreement. They are, therefore, not presented here.

SUMMARY.—It is thus apparent that a number of factors affect the quantity of poinsettia nectar secreted. In the experiment lowered temperature, diminution of light, reduced air pressure, and drought all caused a decrease in secretion, while an increase in the degree of saturation of the air resulted in nectar dilution. A reasonable assumption is that nectar production in other plants is also affected by numerous factors. Since insect activity on blossoms is influenced by the nectar secretion, investigation of this phenomenon should result in great benefit to seed, fruit, and honey producers.—1-6-40.

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# New Equipment for Heating Honey

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Honey, when extracted, is generally in the liquid form but if kept for a period of time the dextrose content changes to the crystalline form. The American public prefers liquid honey which means that most honey must be liquefied before it is sent to market. Heating honey liquefies it but excessive or prolonged heating breaks down the proteins and colloids which then impart to honey a characteristic and undesirable burnt flavor.

Equipment now in use heats honey in large quantities. Tanks ranging in capacity from 100 pounds to two tons are used.

Honey resists the penetration of heat so that prolonged heating is required before all the honey in a tank is brought to the desired temperature. Temperatures as low as 160 degrees F. bring about measurable changes in honey of light color when maintained for as long as fifteen minutes. Dark honey, such as buckwheat, is more easily damaged than is light honey.[1]

A dry heating chamber was built to be used as experimental equipment. Further developments were to be gauged from results obtained with this chamber. Electricity was the source of heat. The chamber was small but large enough for practical use by the small beekeeper. It was 28 inches long, 22 inches high and 18 inches deep. It was made from three-fourths inch tongue and grooved white pine and was insulated with a layer of aluminum foil and one-half inch of celotex.

Two 60 pound cans or 120 pounds of honey in pails or bottles could be heated in the chamber at one time. An electric unit 22 inches long by 1½ inches wide with a capacity of 500 watts was used to generate heat. The wall behind the unit was covered with galvanized sheet iron for a distance of six inches beyond the unit in all directions. The unit was placed in the center of the rear wall one inch from the sheet iron. A baffle board was then fastened one inch in front of the unit and was protected with sheet iron the same as the back of the chamber. An open space of four inches was left at the top of the board and a similar space at the bottom. The space between the board and the wall acted as a flue which set up a circulation of hot air throughout the chamber.

Readings were taken with a thermometer in different parts of the chamber and it was found that the temperature differed as much as 30 degrees between the top and bottom of the chamber.

The heating unit was then placed 2 inches above the bottom of the chamber. The honey was placed on a slatted shelf above the unit. This arrangement heated the honey more evenly but was not satisfactory since honey occasionally spilled onto the unit and decreased its efficiency.

A fan was then placed at one end near the top of the chamber and the unit was returned to the rear wall in its original position. The forced air current provided a much more even distribution of heat but the honey at the far end of the chamber liquefied first. The electric fan was then placed on the floor in the center of the chamber and a current of air was forced up between the baffle board and the wall of the chamber. This arrangement gave a satisfactory distribution of heat. The honey at the top of the chamber, however, liquefied first since the air lost some of its heat as it passed over the containers. The difference was not great enough to be serious.

It was soon noticed the heat affected the oil in the motor so that the motor had to be placed on the outside or be oiled each time the chamber was used.

A large chamber of this type was then designed for one of our commercial beekeepers. This chamber was made large enough to hold about one and one-fourth tons of honey in 60-pound cans. The cans were arranged in four tiers of ten 60-pound cans to the tier. The chamber was insulated with four inches of rockwool and provided with a 3.8 kilowatt battery of strip heating units.

A thermostat was set for 160 degrees F. and each tier of cans was removed when the honey was heated to about 140 degrees F. Approximately 24 hours were required to heat the entire batch of honey. As the cans were removed from the dry chamber, the honey was poured into a large heating tank. This tank was provided with a water jacket and held 600 pounds of honey. The water surrounding the tank was heated with a gasoline burner.

The temperature of the honey in the large tank was raised to 170 degrees F. which required an additional four hours of heating. The honey was then run into bottles and packed in paper shipping cases. The person bottling the honey required an additional period of about three hours and a half to empty the tank which meant that some of the honey was heated to 160 degrees or higher for at least 7 hours. The bottled honey remained hot still longer since the paper cartons acted as insulators.

Doubt soon arose as to the efficiency of this system. In order to check the quality of the honey obtained, small quantities of crystallized honey were taken from several of the sixty pound cans and kept as a sample. This honey was carefully heated, then cooled as soon as it became clear.

[1] Dr. E. F. Phillips, Gleanings, Oct. 1939, 614.

The sample was compared with a similar quantity of bottled honey. It was plainly evident that the bottled honey had been seriously overheated since it had become darker in color and impaired in flavor.

The first piece of equipment built to remedy this condition was a smaller dry heating chamber. It was made 76 inches

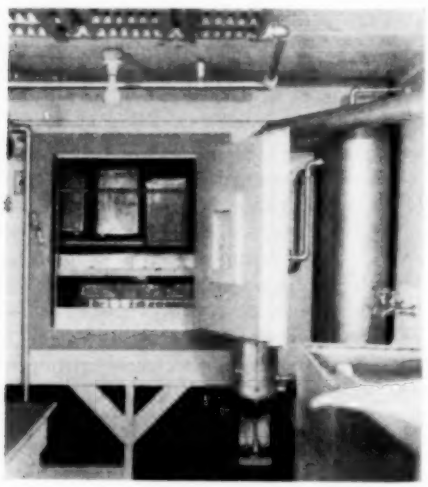

FIG. 1.—The dry heating chamber.

long by 38 inches deep by 54 inches high. A strong frame of two by fours was covered on the outside and white pine and on the inside with pressed board. The space between the walls was insultated with rockwool. Heat was provided by two batteries of strip heating units of 1.8 kw. capacity each. The units were placed on the rear wall of the chamber about 10 inches apart. A strong fan was placed on the bottom of the chamber in such a position that it could drive a current of air over both of the units.

The wall behind the units was covered with a sheet of galvanized iron which extended to the top of the chamber and 12 inches beyond the units in the other directions. Two sheets of galvanized iron were bent so that they could be nailed to the wall and leave a space of one inch between the metal and the flat surface except where the metal was nailed. Two additional sheets were cut two inches shorter than the first but were bent in the same manner. The second pieces were riveted to the first so as to leave a one inch space between the two. The top and bottom of all the inch spaces were left open. The heating units were bolted to the second or outer sheets with a one inch air space between the unit and the sheet metal. Each set of two sheets of metal and a heating unit was bolted together then fastened to the wall of the chamber as one piece. When the units were in place they were 10 inches apart and had three air spaces between the units and the wall of the chamber. The top and bottom of each space was open to permit a free circulation of air which carried away the heat. This arrangement is essential for greatest efficiency and to prevent a fire hazard. The wall of the first chamber caught fire which indicated rather forcefully that a single sheet of iron was not sufficient insulation. When in place each unit was 16 inches from the top of the chamber.

A piece of sheet iron was fastened to the back wall and the top of the chamber directly above the units. It formed a quarter circle and deflected the heat into the chamber. Two pieces of sheet iron were then placed between the units and the honey containers. These were fastened to-

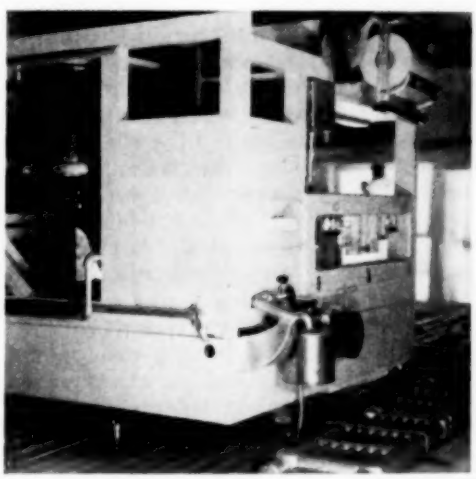

FIG. 2.—An end view of the heating and cooling equipment showing thermostat and overflow.

gether with an inch air space between, the same as the first two sheets placed on the wall. They were one inch forward from the units and were open at top and bottom. All four sheets on either side of the units extended 10 inches above the units and 8 inches below them. There was also a space of 4 inches between the ends of the units and the sheet iron. A small piece of

pressed asbestos 5 inches square was placed on the sheet iron opposite the connections on the heating units. The asbestos was riveted to the metal to form an insulator between the metal and the connections. It prevented a contact should the metal accidently be pushed against the live bolt.

A 10 inch fan was placed below the lower openings of the sheets of metal. The fan provided a forced draft over the units between the sheets of metal and throughout the chamber. A thermostat was installed in the top of the chamber and was set for 140 degrees F.

The sixty pound cans were placed in two rows of six each. Each row of cans rested on two bars. The bottom of the cans rested on one iron bar 2 inches in diameter while the side of the cans rested on the second smaller bar. Each can slanted a little to one side when in position so the melted honey could drain out. It was found that if the cans were heated in an upright position, the crystallized honey clogged the opening and the honey did not run out until nearly all the contents of the can had been liquefied. When the cans were about empty they were tipped in the opposite direction so the last of the honey could drain out.

A pan was made to catch the soft crystals and liquid honey as it dropped from the cans. The pan was three inches deep, 54 inches long and 16 inches wide. It was provided with a 20-mesh screen on each end. The pan was placed in a strong frame made of 2×2 strips and was hung from the two bars used to hold the cans. As the honey became liquid it dropped from the cans then passed through the screens and into a large oblong tank below. If the honey liquefied too rapidly it ran over the sides of the pan and dropped into the tank.

The tank was 60 inches long, 24 inches wide, and 13½ inches deep. It held the entire contents of the 12 cans. This tank was first placed on the bottom of the chamber but it was found that better results were obtained when the tank was placed on a strong stand so the hot air could circulate on all sides and bottom. The tank was made of stainless steel and placed in a box built with inch and a half lumber. The liquid honey drained from the tank into a honey pump placed at a lower level.

From the tank in the chamber the honey was pumped into a second tank located near the ceiling of the honey room. The upper tank was 60 inches long, 30 inches wide and 11½ inches deep. Each of the tanks sloped towards its outlet. There was two inches slope for the length of the tanks and one for the width.

The honey left the upper tank and passed through a coil of block tin tubing

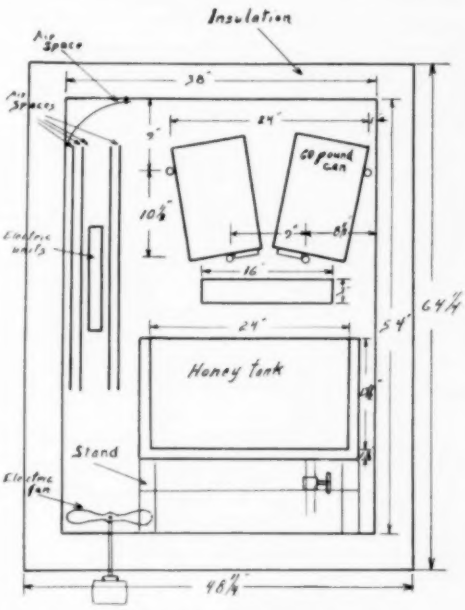


FIG. 3.—Drawing of the dry chamber.

submerged in water. The connection between the tank and the tubing was made of inch and a quarter tubing with a valve to regulate the flow of honey.

The heating coil consisted of 18 feet of tubing and was five-eighths inch, inside diameter. The tubing was enclosed in a small tank 12 inches in diameter by 18 inches high. This tank was provided at the top edge with an overflow to allow for the expansion of water as it heated. The overflow chamber was a galvanized iron bucket with a capacity of about two quarts. When the equipment was put into operation, water was turned in the tank until it appeared in the bottom of the overflow.

A circular immersion heating unit of 4 kw. capacity was placed in the bottom of the tank. A thermostat was then placed near the top center to keep the water at a constant temperature. A thermometer was also placed in the tank to indicate

the water temperature. The whole tank was enclosed in a wooden box and insulated with three inches of rockwool. The water temperature was held 10 degrees higher than the desired temperature of the honey. A second thermometer was placed at the outlet of the tin tube. The honey was heated from 95 degrees F. to 175 degrees (a somewhat lower temperature may be desirable) during the time it passed through the coiled tube. If it were desirable to heat a larger volume of honey a larger tube could be used. Tests indicated that a shorter length of tubing might be used, possibly 15 feet of three-fourths inch tubing. It was also found that the tubing had a tendency to accumulate refuse making a larger tube desirable so that a larger quantity could be heated before the tube was cleaned.

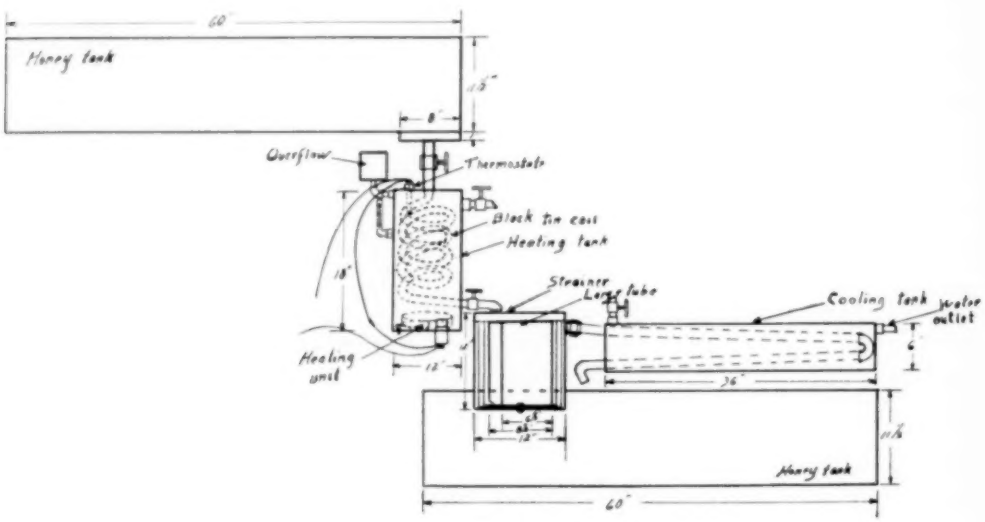


FIG. 4.—Drawing of the heating and cooling equipment.

The strainer was built in a small open tank of stainless steel. It was 16 inches in diameter by 12 inches deep. Two stainless steel screens were placed in it; one was made of 40-mesh screen and the other of 100-mesh. After testing this strainer it was felt that some improvements could be made. Honey remained in this tank for 30 minutes, which was too long. Accordingly a second strainer was designed (but not built) with the following specifications.

The tank was 12 inches in diameter by 12 inches deep: The larger 100-mesh screen was 10½ inches in diameter, and the smaller 40-mesh screen 9 inches in diameter. Both screens were 11 inches deep. In addition, a tube of solid material was made. The tube was 8½ inches in diameter by 10 inches deep with a solid bottom but an open top. A piece of metal 4 inches wide by 10 inches deep was formed into a half circle about 2½ inches in diameter. It was soldered to the inside of the tube so as to make a tight chamber. A hole about 1½ inches in diameter was cut in the bottom of the tube and on the outside of the small chamber. When honey entered the top of the chamber it left through the small opening and then flowed through the screens and out of the tank. This tube may be held in place either with a bar fastened across the top of the straining tank or with a bolt in the center of the bottom. If a bolt is used a hole should be bored in the bottom center of the tank, two screens, and the tube. A thin circle of pressed fibre would be used as a gasket between parts. The bolt would hold all the parts tightly together and could be removed when the screens required cleaning. A petcock could be placed in the bottom to drain the last of the honey after the operation was over. The time required for a batch of honey to pass through the strainers and out of the tank would be reduced from 30 minutes to 9 minutes when honey was heated at the rate of a ton every 10 hours. The opening of the heat-

ing coil was directly above the small chamber and was kept above the constant level of the honey in the tank. It was found that if the opening was in contact with the honey, refuse collected in the tin tube and shut off the flow of honey.

The honey left the strainer by an opening located 2½ inches from the top of the tank. A section of one inch block tin tubing was connected with both the opening and the cooling chamber.

The cooling chamber consisted of an oblong copper tank 6 inches square and 36 inches long. The one inch tube entered the chamber at the top of one end extended to the opposite end and back then left the chamber at the bottom of the end it entered. There was 6 feet of tubing in the chamber. The bottom end of the tube poured the honey into a third tank, the one from which the bottling was done. The tube connecting the strainer to the cooling tank was fastened with a coupling so the strainer could be removed if necessary.

A current of cold water passed through the cooling chamber. The water entered at one end and flowed out of an opening at the opposite end. The flow of water was controlled with a valve and the volume regulated the temperature of the honey. The temperature of the honey was reduced from 165 degrees F. to about 95 degrees during the time it was in the cooling chamber. Approximately one gallon of water was required to cool one gallon of honey. The temperature of the water is 52 degrees F.

The cost for electrical current was eight-tenths of a cent a pound for the entire process. The current rate at the honey house was two cents per kw. Tin solder was used throughout. If the heating chamber for sixty pound cans could be located above the rest of the equipment the second storage tank for honey could be eliminated. This arrangement would also remove the need for a honey pump.[2]

SUMMARY.—The equipment developed utilized electricity and thermostatic control for the entire process of heating the honey. There were two stages of heating, the first to liquefy the honey and get it out of the sixty pound cans; the second, to heat it to a temperature high enough to retard crystallization after it was bottled. A dry chamber with a forced air draft was used for the first part and a block tin coil submerged in hot water for the second part. After it was heated to a temperature of 175 degrees F. the honey was passed through a 100 mesh screen and cooled to a temperature of 95 degrees F. before it was bottled. Stainless steel, block tin, or chrome was used throughout where honey came in contact with metal. The time required for heating the honey in the coil was about one minute. To this must be added a nine minute lag in the strainer. In all, the honey was hot for a period of only 10 minutes. The quick heating and cooling left the honey with nearly its original flavor and color. The cost, at two cents per kilowatt, was eight-tenths of a cent per pound for current for the entire process.—1-22-40.

[2] Recognition and thanks are extended Mr. Roy Howell of Saylorsburg, who helped design the equipment, kept records of its workings and stood the expense of building it and making repairs.

## ERRATA

Volume 32, No. 5, page 687, second column, line 13, for *insignificant* read *significant*.

Volume 33, No. 1, Table of Contents, second page, for *186* read *189*.

Page 98, figure 7 is reversed; therefore in legend *left* should read *right* and *right* should read *left*.

Page 202, first column, under Literature Cited, first line, *Entomogeous* should read *Entomogenous*.

# SCIENTIFIC NOTES

## Definition of the Word "Rotenoid"

In the November 1939 issue of the Annals of Applied Biology (vol. 26, pp. 649–683), R. R. LeGeyt Worsley, biochemist of the East African Agricultural Research Station, published a paper entitled "The histology and physiology of rotenoids in some Papilionaceae. I." Worsley defines rotenoids "as those naturally occurring substances which give a blue or green color when treated with strong (about 75 per cent) nitric acid followed by strong ammonia solution."

The word "rotenoid" was coined, not by Worsley, but apparently by the American chemist Dr. Hyym E. Buc, who used it in an application for a United States patent, filed March 12, 1931, which was granted him on September 3, 1935, as No. 2,013,028. Buc defined rotenoids as follows: "The term rotenoid is used to designate insecticidal principles of the same plants (derris and cubé) which are not exactly identical with rotenone in their chemical constitution but have a similar insecticidal action." Buc also uses the word "rotenoids" in U. S. patent 2,042,296 granted him on May 26, 1936.

L. A. Mikeska, in U. S. patent 2,066,184, applied for October 29, 1932, and issued December 29, 1936, speaks of the toxic insecticidal ingredients of fish-poisoning plants such as derris and cubé as follows:

> "These toxic ingredients have been extracted from the fish poisoning plants by use of solvents and upon separation from the solvents were found in two forms. One form was crystalline in its structure, which is known as rotenon, while the other was non-crystalline which is known to be a mixture of deguelin, tephrosin, toxicarol, etc., and which we shall hereafter call rotenoids. Both forms are toxic when applied to insects."

The definitions of Worsley, Buc, and Mikeska are not identical. Worsley defines "rotenoids" in terms of a color reaction, whereas Buc and Mikeska define the word in terms of insecticidal action. Worsley's definition of rotenoid includes rotenone, whereas the definitions of Buc and of Mikeska exclude it.

The color test referred to by Worsley is that originated by Durham and first described by Gimlette ("Malay Poisons and Charm Cures." 2nd ed., p. 221) in 1923. Jones and Smith (Ind. Eng. Chem., Anal. Ed. **5**: 75–76. 1933) carefully studied the Durham color test and found that deguelin, as well as rotenone, gives a blue color and that toxicarol gives a greenish color when treated with nitric acid followed by ammonia. Because of the evanescent nature of these colors, it is possible to obtain only roughly quantitative estimates of the amount of rotenone, deguelin, etc., present by the Durham test and then only if the modification of the method proposed by Jones and Smith is followed. For this reason the writer believes it unwise to define "rotenoid" in terms of the Durham color test. Better color tests for quantitative purposes for the constituents of derris and cubé have been proposed by Goodhue (Jour. Assoc. Official Agr. Chem. **19**: 118–120. 1936), by Rogers and Calamari (Ind. Eng. Chem., Anal. Ed., **8**: 135. 1936), by Meyer (Rec. trav. chim. **55**: 954–958. 1936), and by Cahn, Phipers, and Boam (Jour. Soc. Chem. Ind. **57**: 200–209. 1938). Jones (Ind. Eng. Chem., Anal. Ed. **11**: 429–431. 1939), who has recently compared all colorimetric methods proposed for the evaluation of derris and cubé roots, concludes that the Goodhue color test is the best for estimating the insecticidal value of these roots to houseflies, and that the Meyer color test is the best for getting a rough idea of the total materials of the rotenone type.

"Rotenoid" promises to come into use in the literature of applied entomology. It is a useful word but should be more carefully defined. The writer ventures the following definition: A rotenoid is a substance other than rotenone, but structurally related to it, naturally occurring in leguminous fish-poison plants (*e.g. Derris, Lonchocarpus, Mundulea,* and *Tephrosia*). Rotenoids may be quantitatively determined by the Meyer (Rec. trav. chim. **55**: 954–958. 1936) color test. Examples of rotenoids are laevodeguelin, laevo-alpha-toxicarol, sumatrol, and elliptone.—2-19-40.

R. C. Roark, *United States Department of Agriculture, Bureau of Entomology and Plant Quarantine.*

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## Combined Derris-Nicotine Dusts for Cabbage Insects

The recently recommended use of organic dust insecticides such as derris and cubé, has raised a problem in compatibility of insecticides for the truck growers in southeastern Wisconsin in controlling cabbage insects. In this region infestations of cabbage worms and cabbage aphids frequently occur together and an insecticide adapted to control of both chewing and sucking insects is necessary. Of the organic materials used thus far for the control of cabbage worms, dusts containing rotenone-bearing materials have been among the most satisfactory. For the control of cabbage aphids, however, nicotine dusts are generally considered the most satisfactory. A combination of these insecticides should be effective against both worms and aphids, but with the diluents ordinarily used, they are incompatible, and their use in combination has not been recommended.

In 1938, the writers undertook to determine the possibility of making a derris-nicotine dust that would be effective against both cabbage worms and aphids. Previous studies by the authors[1] revealed that when alkaline dust diluents were used with rotenone-bearing roots they weakened the insecticidal effect, whereas an acid diluent such as sulfur did not. Further tests showed that when sulfur was added to highly alkaline materials, the latter did not cause deterioration of the rotenone-bearing roots, even though these mixtures remained alkaline. The fact that a mixture of sulfur and hydrated lime to which nicotine sulfate is added evolves nicotine very readily, was shown by Thatcher and Streeter,[2] and since a mixture of sulfur and hydrated lime appears to cause no rapid loss in toxicity of rotenone-bearing roots, various combinations of these materials were tested in a preliminary way against the cabbage aphid.

The dusts tested (Table 1) were mixed just prior to application, and were applied by means of a knapsack bellows duster. The plot consisted of cabbage plants in three blocks of thirteen rows each. A single treatment was made to one row of twenty plants in each block. Each insecticide treatment was tripli-

[1] Ann Rpt. Wis. Agri. Expt. Sta. Bul. 438, p. 124, 1937 and Bul. 443, p. 47, 1939.

[2] Thatcher, R. W. and L. R. Streeter, Factors Which Affect the Volatility of Nicotine from Insecticide Dusts, New York Agri. Expt. Sta. Bul. 501, March 1923.

**Table 1.—Cabbage aphid populations as affected by dust insecticides under field conditions.***

| Treatment | | Per Cent Reduction in Aphid Population | |
|---|---|---|---|
| Material | Pounds | 1 day after dusting | 5 days after dusting |
| Derris[1] | 25 | | |
| Hydrated Lime | 37.5 | | |
| Sulfur | 37.5 | | |
| Nicotine Sulfate[2] | 5 | 96.4 | 86.7 |
| Nicotine Sulfate[2] | 3 | | |
| Sulfur | 47 | 100.0 | 82.0 |
| Derris[1] | 25 | | |
| Sulfur | 37.5 | | |
| Hydrated Lime | 37.5 | | |
| Nicotine Sulfate[2] | 5 | | |
| Supplement[3] | 1.5 | 94.6 | 87.4 |
| Nicotine Sulfate[2] | 3 | | |
| Hydrated Lime | 47 | 99.0 | 80.0 |
| Derris[1] | 25 | | |
| Sulfur | 75 | | |
| Nicotine Sulfate[2] | 5 | 94.0 | 75.4 |
| Derris[1] | 25 | | |
| Hydrated Lime | 75 | | |
| Nicotine Sulfate[2] | 5 | 80.5 | 72.7 |
| Derris[1] | 25 | | |
| Talc | 75 | 58.4 | 59.4 |
| Derris[1] | 25 | | |
| Talc | 75 | | |
| Supplement[3] | 1.5 | 48.5 | 57.4 |
| Derris[1] | 25 | | |
| Sulfur | 75 | 34.6 | 39.4 |
| Derris[1] | 25 | | |
| Hydrated Lime | 37.5 | | |
| Sulfur | 37.5 | | |
| Supplement[3] | 1.5 | 39.1 | 34.7 |
| Derris[1] | 25 | | |
| Hydrated Lime | 75 | | |
| Supplement[3] | 1.5 | 48.0 | 14.7 |
| Derris[1] | 25 | | |
| Sulfur | 75 | | |
| Supplement[3] | 1.5 | 34.6 | 18.7 |

* Temperature at time of application 85°F.
[1] 5% rotenone, and 17% total ether extractives.
[2] 40% nicotine.
[3] Sodium lauryl sulfate.

cated and arranged according to the randomized block method. Aphid populations were estimated by determining the total number of aphids present on five plants chosen at random in each row treated.

Results of these tests indicate that a derris-nicotine dust with sulfur and hydrated lime as diluents is approximately as effective in the control of the cabbage aphids as a hydrated lime-nicotine sulfate dust. This same derris-nicotine combination dust has given excellent control of cabbage worms, as well as fair results when tested against the pea aphid. A common derris dust, with and without supplement, appeared to be ineffective in controlling cabbage aphids.—2-19-40.

J. W. Brooks and T. C. Allen, *University of Wisconsin, Madison.*

## β, β′ Dichloroethyl Ether for the Control of Gladiolus Thrips[1]

During August 1938, gladiolus plants growing in field plots were sprayed with a solution consisting of a saturated solution of β, β′-dichloroethyl ether (8.3 cc. per 1. of water), 0.1 per cent pyrethrum resins,[2] and 0.5 per cent *Tergitol* 7 penetrant. The last named ingredient (Wilkes and Wickert, 1937) is a sulphated alcohol used as a wetting agent. The plants were sprayed by means of a hand sprayer and counts of living and dead gladiolus thrips (*Taeniothrips simplex* Morison) (adults and larvae) were made 24 hours after the spray was applied. The kill on different days ranged from 81.3 per cent to 95.6 per cent. The number of individuals counted in each test ranged from 125 to 175. The natural mortality was 29 per cent.

A spray solution of 0.1 per cent pyrethrum resins,[2] and 0.5 per cent *Tergitol* 7 penetrant gave kills of from 31 per cent to 88 per cent, which were appreciably lower than was obtained when β, β′-dichloroethyl ether was used.

A spray solution of 0.5 per cent *Tergitol* 7 penetrant in a saturated solution of β, β′-dichloroethyl ether gave a kill of 78.1 per cent. "Purple Glory" and "Senorita" showed no injury after repeated sprayings with the above named sprays when examined a week later. However, severe yellowing of the foliage was observed on both varieties two weeks later.

During the winter of 1938, the same sprays at the same concentrations were applied to gladiolus plants in the greenhouse. Injury occurred on the more delicate varieties such as "Miss Greeley," "W. H. Phipps," and "White Butterfly," when β, β′-dichloroethyl ether was used, while with "Senorita" and "Purple Glory" the injury was again delayed. It is possible that injury may be avoided by using a lower concentration of *Tergitol* 7 penetrant. It is of interest also to note that with proper concentration and distribution of the vapor β, β′-dichloroethyl ether has been used as a greenhouse fumigant without causing injury to the foliage of gladiolus (Wilcoxon & Hartzell, 1938).—1-26-40.

Albert Hartzell and George F. McKenna, *Boyce Thompson Institute for Plant Research, Inc., Yonkers, New York.*

### Literature Cited

**Wilcoxon, Frank,** and Albert Hartzell. 1938. Experiments on greenhouse fumigation with β, β′-dichloroethyl ether. Contrib. Boyce Thompson Inst. 10(1):47–56.

**Wilkes, B. G.,** and J. N. Wickert. 1937. Synthetic aliphatic penetrants. Indus. & Eng. Chem. **29:** 1234–9.

[1] Materials were furnished by Carbide and Carbon Chemicals Corporation, New York, N. Y.
[2] 0.02 per cent total pyrethrins.

## The Bee Loss Situation in Utah

Bee losses have been reported periodically in Utah for many years. Because of such losses the general subject of the relation of agricultural sprays and dusts to beekeeping was discussed at the Beekeepers Annual Conference held in Salt Lake City, December 14, 1936.

Bee losses have been attributed to a number of causes. Beekeepers have frequently ascribed losses in areas near smelters to smelter smoke; and those occurring in early spring to orchard spraying; loss following sugar-beet webworm control has been supposed to be caused by bees seeking water in sprayed beet fields during the morning, and procuring paris green along with water. When heavy losses occurred in many apiaries during the latter half of June and the first two weeks of July 1939, many beekeepers in Utah and Salt Lake counties believed the bee mortality to result from grasshopper baiting operations. Beekeeper objections to such baiting resulted in decreased grasshopper control activity on many farms. Bee losses in Weber, Davis and Box Elder counties which occurred during this time were suspected of having been caused by sprays applied to control the sugar-beet webworm. The cause of similar bee losses in Wasatch County, in the Heber area, where no grasshopper bait had been spread, was not evident.

Samples of bees collected in Davis County during July, 1939, were submitted to the Washington office of the Division of Bee Culture, United States Bureau of Entomology and Plant Quarantine. This office found arsenic present but no trace of copper, which would be expected to be present if the losses were caused by the paris green in webworm spray. Arsenic has been present in or on most bees analyzed during recent years. The fact that bees may accumulate arsenic on their bodies while visiting plants sprayed or dusted with arsenicals makes it difficult to determine by present methods whether or not particular samples of bees definitely had been killed by the arsenical found to be present.

The belief that grasshopper bait was responsible for bee losses during 1939 was reflected in the following statements, taken from the United States Department of Agriculture, Agricultural Marketing Service-Semi-monthly Honey Report No. 513, October 2, 1939: "Losses of bees from grasshopper poison bait have been heavy in Utah and other states, and from spray poisoning in the Northwest. . . . Thousands of colonies of bees have been killed by the poison in grasshopper bait, which has been used lavishly this season by Utah farmers, . . . but surviving colonies are in much better shape since the poison was washed away by the rains." No. 515 of this same publication, dated November 1, 1939, states: "The summary statement for the last half of September stated that: 'Losses of bees from grasshopper poison bait have been heavy in Utah and other states.' The implication of poison bait in these losses based on reports received from our cooperators, has not been confirmed. An attempt is being made by the Department and State agencies to definitely determine the cause of these losses but evidence now available to the Department indicates that grasshopper bait is not attractive to bees and its distribution does not result in colony losses."

Government-supplied grasshopper bait was not used lavishly in Utah during 1939; only 314 tons of bran, 20 tons of sawdust, and 3,646 gallons of sodium arsenite were used in the entire state during the season. This was approximately half the bait needed if grasshopper losses had been held to a reasonable low level.

Tentative plans have been drawn up for a cooperative federal-state study of the bee loss problem in Utah to begin in 1940. Investigations conducted by the writer, assisted by W. P. Nye, for the Utah Agricultural Experiment Station from August 1 to September 15, 1939, indicate that during this period bees were not attracted to grasshopper bait and numerous combinations of bait materials, even when test materials were located near large bee yeards. Each material investigated was spread much more heavily than is recommended for grasshopper control, over sheeting covering 50 square feet in area. These heavier dosages remained moist much longer than would grasshopper bait flaked out thinly at the rate of but twenty pounds of wet bait per acre. There is a possibility that at times of serious pollen or nectar shortage, bees might work over any exposed or carelessly applied poisoned bran bait deposits, just as they sometimes work in available dry bran or sawdust during early spring.—1-8-40.

G. F. KNOWLTON, *Utah Agricultural Experiment Station, Logan.*

## Serious Reactions to Bee Stings

There has been a course offered in beekeeping at the Alabama Polytechnic Institute at Auburn, for more than 20 years. During this time the number of students enrolled annually has varied from 10 to 42. Until the spring of 1939 there had not been any serious reaction to stings by the students of any of the classes during the entire period. Previously a member of the Department of Zoology-Entomology at Auburn had exhibited a serious case of supersensitiveness to bee sting. This person helped the writer work with bees whenever the opportunity presented itself. When stung he showed such unusual reactions as violent itching and reddening of the palms of the hands, regardless of where he had been stung. The reaction for several years never went beyond such manifestations. In 1934, during a visit to a commercial bee yard, one sting on the elbow produced very violent reactions resulting in unconsciousness within 10 minutes. The subject first experienced a metallic taste in the mouth; then his face became very red and finally turned blue just before he lost consciousness. During unconsciousness there was a lack of control of the muscles governing urination and defecation. Upon the administration of adrenalin the subject regained consciousness and was practically normal in about four hours time.

In 1939 a graduate assistant in apiculture while working with her colony of bees was stung once on the middle finger. In a few minutes she had become dizzy and exhibited such reactions as violent reddening of the face, a numb lower jaw, popping eardrums, ear lobes swollen, and the breaking out of hives on the body. After lying down for about three hours the patient recovered. This student had been stung a few times in 1938 without exhibiting any unusual reactions. Following this, three other abnormal cases occurred. The first and the second were those of students who were taking the course in apiculture. Case 1 received one sting on the wrist and became very red in the face, his eardrums felt as if they would pop, his lower jaw became numb and he was dizzy. Case 2, who was stung once on the calf of the leg, and once on the finger, exhibited a very red face, and extreme itching condition of the scrotum and of

the feet particularly between the toes. The last case was that of a negro who was stung while passing the bee yard. His only visible reaction was fainting. The victims of the last three mentioned cases were promptly carried to a doctor who administered adrenalin. All three patients made complete recovery withing a few hours. To the knowledge of the writer the graduate assistant is the only one of the five patients who has been stung since showing supersensitiveness. She was stung once on the finger about three weeks after her unusual experience, but showed no adverse reaction.

Why should there have been four severe reactions to stings in the spring of 1939 and none in the 19 preceding years of student activity with bees? Could it have been caused by some unusual condition of food, weather, or other abnormal conditions affecting the bees? Or, could it have been a body condition of those affected? Dr. B. L. Beck discusses the condition in his book "Bee Venom Therapy" as follows:

"If we try to apply the laws of anaphylaxy to beestings, we are certainly confronted with another complex problem. Beekeepers who for many years considered themselves immune, and were stung by numerous bees in a single day without exhibiting any reaction, sometimes, if stung by one bee, become gravely ill. How can we give an adequate explanation for such a sudden loss of immunity? One of the explanations we could offer is that such people have only a "skin immunity" and when the venom is injected into the veins and does not pass through the skin, they react very violently. This comment seems rather fantastic but still we have to give it consideration. Another explanation would be that some other temporary constitutional derangement aggravates, perhaps through *negative instrumentality*, the action of the venom. We note repeatedly that a veteran beekeeper's reactions are very severe after one sting, but when stung a couple of days later, he is again in the usual non-reactive state. I noticed numerous cases where the reactions were very severe after a meal, *especially after a hearty meal.*"—12-27-39.

F. E. GUYTON, *Auburn, Alabama.*

## "White Marked Spider Beetle" or "Pilferer"

White marked spider beetle is the approved common name for *Ptinus fur* L. but the name should not be used since the revised edition of Farmer's Bulletin 1260 (1938) gives a description and a picture of *P. tectus* Boield as the white marked spider beetle. To be consistent this other one would have to be named the "hairy white marked spider beetle." Instead of two words for a common name, which should usually be the maximum, there would be five, only twenty per cent worse than the approved name and the dubbing would be consistent. The name white marked spider beetle must now create misunderstandings.

Inconsistency is characteristic of the common names adopted by the Association. To pick one, the cow pea weevil; if the Association wishes, the name weevil may be narrowed down to apply only to species of Rhynchophora and one of the complaints of the man whose portrait adorns the front cover of each issue of the Journal will have been removed. Harris stated that the word weevil applied to six different kinds of insects of which two were moths, two were flies and two, beetles. Applying the name weevil to all orders of insects creates no distinctions.

I like the word weevil; it corresponds to the German *Wippel, Weibel* and *Getreidewippel*, all applied to the granary weevil. Nobody knows exactly where the word comes from. My private opinion is that it connects with the German word *Waibel* or *Webel*, as it is still used in *Feldwebel*, for corporal. *Waibel* means constable, guard or sentry; possibly the weevil is the sentry, the kernel of grain his sentry-box.

When the word weevil had been used for the cow pea weevil, not a true weevil at all, it became necessary to indicate that the real weevil in cow peas was the "real thing." There was then invented a term to serve as a superlative for the term weevil, and the name cow pea curculio appeared. Weevil thus becomes the positive to the superlative curculio and means merely a beetle that resembles the curculio. The English, by the way, don't seem to like the American lax use of the word weevil. British government Leaflets 61 and 162 indicate a clear distinction between a weevil and a mere beetle.

I also like the word curculio. The proverb of Plautus, "*Curculiunculus minutus fabulare*" meaning "useless talk," would, in its verbal translation, not indicate a high respect for what entomologists do. Curculio, to the old Roman, apparently meant only "voracious animal." It meant grain moths just as much as grain weevils. There is a suspicion that it connects with the present Italian "*gorgogliare*" the words gargle and gurgle and the Latin *gurgulio*, meaning gullet.

But to come back to the issue, whether Linnaeus' somewhat harsh "thief-beetle" should be used. I think that Linnaeus states his case in a letter published by Goeze in 1776: "I know this fellow and have had to pay him dearly. He wants to destroy everything that is dead, even food and the daily bread. I tried to induce him to leave alone my insects and plant collections, but he knows no mercy. I always put a pill of musk in each box of insects,but he went and bred in the musk. President Carleson sent me a metal box with snuff, and whom do you think I found inside . . . ?"

Pilferer, a petty thief, as Webster defines the term, seems to be characteristic, a good translation of the Latin and, being a single word, is therefore the ideal of a common name. To overcome the objection that what is good in Sweden might not be good here I bring a piece of American entomological history. It refers to a meeting of the Entomological Society of Washington on December 8, 1887. The record reads: "Mr. Lugger showed to Mr. John B. Smith a naphthalene cone in which a *Ptinus* larva had pupated."

I hold with the late Dr. Britton:[1] "Wait until an appropriate name comes easily, something that fits, something that will stick." Such a name, I believe, is "pilferer."—1-8-40.

HUGO HARTNACK, *Chicago, Illinois.*

[1] JOUR. ECON. ENT., **30**: 345. 1937.

## A Homemade Device for Maintaining Subzero Temperatures

During the past season (1939) a simple refrigerator, using dry ice as a refrigerant, was constructed for maintaining constant subzero temperatures (Fig. 1). The apparatus consists of three primary parts: A, the dry ice container of galvanized iron 3×4×16 inches with a wedge-shaped bottom; B, a bath for alcohol or *Prestone* made of galvanized iron 7×7×14 inches; and C, a cold chamber 3×6×6 inches, also made of galvanized iron. Thermocouples are placed in glass tubes, D, one in the cold chamber and one in the bath, and the bath is agitated with a motor stirrer, E. All cold parts are insulated with 3 to 4 inches of rock wool, asbestos, and newspaper, and lids, F, cover cold chamber and dry ice container, the lower part, H, containing only the antifreeze bath, and the upper structure, including the dry ice tower, the cold chamber, the thermocouple tubes, and the stirrer all attached to a piece of ply-

wood, J, which in turn is fastened to the lower part by screws about the edge so as to be readily removable.

Constant temperature is maintained by adjusting the depth of the dry ice container in the antifreeze bath. This is done by means of a string (a screw arrangement was found unsatisfactory because of ice formation). At first the container of dry ice is lowered to the bottom of the bath and when the desired low temperature of the bath is approached, the ice is gradually raised to the proper point. A ruler or marked stick may be used as an aid in determining this point. It is important that thermocouples in both bath and cold chamber be used as there is some

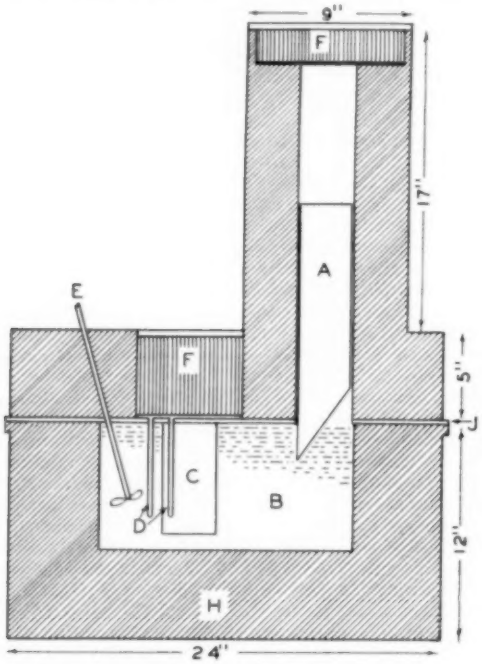


FIG. 1.—Cross section of dry ice refrigerator.

temperature lag between the two, particularly after warm samples have been placed in the cold chamber.

The apparatus is not so desirable as a controlled mechanical device but with experience was found satisfactory for maintaining temperatures as low as $-50 \pm .1$ degree C. for periods of four to eight hours. The addition of a controlled heating element might be of some advantage. The cost of construction is low, not over a few dollars, as the device is made mostly of wood, and it will operate on less than twenty pounds of dry ice per day.—2-15-40.

L. P. DITMAN and G. S. WEILAND, *Maryland Agricultural Experiment Station College Park, Maryland.*

## Big-Eyed Bug Bites Man

On June 16, 1936, a male big-eyed bug, *Geocoris decoratus* Uhler, was observed to light and within a few seconds was felt to pierce the skin upon the side of the writer's middle finger; the tiny piercing bristles of the mouthparts evidently were inserted through the skin. Feeding at this point was continued for one minute and forty-five seconds before the stylets were withdrawn. During the feeding operation the labium at times bent back, allowing for deep penetration of the feeding bristles; at other times the beak would be partially straightened out, evidently accompanied by partial withdrawal of the bristles. Increased irritation frequently accompanied renewed probing activity by the stylets. Complete withdrawal of the feeding bristles was followed in a few seconds by a re-insertion of the parts, the new puncture in the skin being located approximately one-half inch from the first. Feeding occurred continuously at this second point for twenty-five seconds. Both times the feeding bristles were felt to penetrate the skin, definitely causing pain followed by a burning sensation. The latter irritation was similar to the "burning" which followed the sting of a small bee, *Perdita* sp., which had stung the writer upon the back of the same hand approximately three minutes before the *Geocoris* first pierced the skin. Six minutes after the bug stopped feeding, the burning sensation produced by its bite had noticeably lessened. Ten minutes after feeding, a tenderness and reddened spot surrounded the first feeding puncture, this again being surrounded by a white area about three thirty-seconds of an inch wide. The place where the second puncture occurred had developed a slight swelling; this was barely discernible after twelve minutes had elapsed. Irritation continued and the red spot still surrounded the first bite twenty-five minutes after feeding occurred but the white ring had disappeared. (The burning sensation from the bee sting had been entirely lost by this time.) A small pinkish-red dot and slight irritation at the point of feeding were evident two and one-half hours after the skin was first pierced by the *Geocoris*. The writer's hands were not noticeably sweaty when the "bug" bite occurred, a condition which has seemed to encourage leafhoppers of various species to "bite" the writer when he has been at work in summer at night in a hot room, under a bright light.

On September 23, 1936, a *Geocoris decoratus* adult female was noted "biting" the writer upon the skin of the outer part of his arm, as he collected beet leafhoppers on range foothills seven miles northwest of Corinne, Utah. The irritation from this bite could still be distinctly felt at the end of twelve minutes. On several occasions this *Geocoris* species has "bitten" the writer when given the opportunity, while it was being handled in the laboratory.

At Lakepoint, Utah, March 27, 1933, an adult *G. decoratus* was observed to be feeding upon an adult leafhopper, *Aceratagallia sanguinolenta* (Prov.) the air temperature at the time being 61 degrees and the soil surface 78 degrees. On other occasions this bug has several times been observed to feed upon adult and young beet leafhoppers, potato psyllids and pea aphids, nymphal false chinch bugs and upon the small fly *Chloropisca glabra* and upon dead *Lygus elisus* and *L. hesperus*.—2-12-40.

GEORGE F. KNOWLTON, *Utah Agricultural Experiment Station, Logan.*